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CHEMICAL TECHNOLOGY

OR

CHEMISTRY

APPLIED TO ARTS AND MANUFACTURES

VOL. II.

LIGHTING

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CHEMICAL TECHNOLOGY

OR

CHEMISTRY IN ITS APPLICATIONS TO ARTS AND MANUFACTURES

EDITED BY

CHARLES EDWARD GROVES, F.R.S.

EDITOR OF THE JOURNAL OF THE CHEMICAL SOCIETY

AND

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WITH WHICH IS INCORPORATED

RICHARDSON AND WATTS' CHEMICAL TECHNOLOGY

VOL. II.

LIGHTING

FATS AND OILS
BY W. Y. DENT

STEARINE INDUSTRY
BY J. McARTHUR.

CANDLE MANUFACTURE
BY L. FIELD AND F. A. FIELD

THE PETROLEUM INDUSTRY, AND LAMPS
BY BOVERTON REDWOOD

MINERS' SAFETY LAMPS
BY B. REDWOOD AND D. A. LOUIS

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PREFACE.

This volume of Chemical Technology deals with the special application of Fuel to the purpose of producing Light, irrespective of the heat developed at the same time, and as there are many ways in which this is effected, it was necessary to fix on some order of sequence in which the various Sections should be arranged. Something in the nature of historical or chronological succession has been adopted as a matter of convenience, but this relates only to the order in which the various methods of obtaining light came into use, for it is evident that as the means of illumination referred to, in their higher developments at all events, are every one of them still in use, there is no reason to suppose that no further improvements will be made or that they will any of them become obsolete.

In the first Section, that on Oils and Fats, for which we are indebted to Mr. W. Y. Dent, only those which are used for lighting are considered, thus excluding the very large and important class of oils and fats employed for lubrication, or as vehicles in painting or varnish making, or as material for other chemical products. Although the general outline of the technology of these substances remains essentially the same as it was in early times, yet the great progress which has been made in recent years in the machinery used in their extraction and preparation will doubtless continue, resulting in saving both in cost and in labour, besides improving the purity of the product.

Further important advances have been made in the matter of testing these materials, whereby not only can the quality of the product be ascertained, but the presence and nature of foreign substances can be detected, whether they occur as accidental impurities or have been added for the purpose of fraudulent adulteration. Owing to the highly complex nature of the compounds themselves, their very close resemblance one to another, and the ease with which they are decomposed by chemical agents, the tests applicable to them are more or less uncertain in their operation, much depending on an exact attainment of similar conditions and on the experience of the operator. Still, as shown in the section relating to this subject, much has been done to render these tests precise and comparable when made by different observers.

In the Stearine Industry, described by Mr. J. McArthur, there is a somewhat similar condition of affairs, but the entire subject is comparatively modern, involving definite chemical processes. Recently considerable improvements in the direction of larger and more powerful apparatus have been made, enabling the manufacturer to produce a purer article with a

larger yield and less loss of subsidiary products, and these are fully described The process is, of course, the first stage in the manufacture of candles.

The Section on the MANUFACTURE OF CANDLES is written by Messrs. L. Field and F. A. Field. In temperate and northern climates, this is probably one of the oldest industries of mankind, and the candle is essentially the same throughout the ages, although the materials and the machinery employed have varied very considerably. In wax candles, the mode of manufacture remains the same as it was in the Middle Ages, the sole improvement being in the refining and bleaching of the raw material, unfortunately often accompanied by its adulteration with less costly wares. Candles other than wax were formerly entirely of tallow, but now this is almost superseded by paraffin, stearine, and ozokerit. The machinery for making them has undergone an enormous development of late years, enabling the manufacturer to produce a more sightly article with great rapidity and in great quantity. The tallow candle, with its wick requiring constant snuffing, is almost obsolete, but there seems no reason to look for such a fate for the modern candle with improved wick. It is true that for the lighting of large public buildings and for the greater part of domestic lighting, candles have been superseded by gas, petroleum, and electricity; but there are many domestic purposes for which they are still the most convenient form of illuminant, not to mention that there are many who still use them as a matter of personal or artistic preference, and that to an extent which creates a large and increasing demand for them.

PETROLEUM is perhaps the most formidable rival of the candle, and Mr. Redwood has dealt with its technology with great care and thoroughness. At one time supposed to be a rare and isolated occurrence, it is now known to be very widely distributed over the surface of the earth and in enormous quantities. The mechanical skill displayed in the apparatus for boring the oil-wells will strike every one; the elaborate tools used to perforate rocks of all degrees of hardness for many hundreds of feet in depth, with a straight bore of some six inches in diameter, to remove the débris, and to remedy all kinds of fractures and mishaps to tools at those great depths, are wonderful triumphs of mechanical skill. The crude material, when obtained, has to be refined and separated into various products, employed chiefly for illumination and for lubrication, and in these operations of refining and separation considerable advances have been made in reducing the cost, in improving the quality of the product, and in diminishing the loss.

For lighting, petroleum is, and perhaps will remain, in possession of the field outside towns and the larger villages. Where houses are so scattered that gas or electricity cannot well be supplied, it furnishes the main source of light, and with the lamps now available leaves very little to desire either on the ground of cost, health, or safety. The aggregate use thus secured is necessarily very large, and to this must be added what is used in towns by the poorer classes, not to mention those who prefer it to gas as being more cleanly and less destructive to furniture and decorations, and on this account are willing to forego the conveniences afforded by the use of gas.

Much valuable information incorporated in Section IV. (The Petroleum Industry) has been derived from Professor Peckham's Census Report on Petroleum, from Mr. John F. Carll's Reports of the Geological Survey of Pennsylvania, and from other sources acknowledged in the Section. A few illustrations have been taken from the Geological Survey Reports, from Mr. Benjamin J. Crew's work on Petroleum, and from the Catalogue of the Oil Well Supply Company of Pennsylvania, whilst others have been taken from papers by the author of this Section published in the "Journal of the Society of Chemical Industry"; for part of the material employed in the preparation of the maps he is indebted to Mr. John C. Welch of New York. The account of the Shale Oil Industry is largely based upon particulars supplied by the late Mr. T. A. Aitken, and some of the illustrations have been taken from papers by Mr. R. H. Brunton ("Minutes of Proceedings of the Institution of Civil Engineers"), and by Mr. George Beilby ("Journal of the Society of Arts"), whilst others have been reproduced from patent specifications.

The Section on Lamps is divided into two principal subdivisions—namely, lamps burning fat oils, and lamps burning mineral oil. The history of the former has been traced from the earliest times, and all the important examples of the different varieties of this class of lamps have been described. The mineral oil lamp, however, is of far greater importance, and the very complete and elaborate series illustrated here will show the amount of mechanical skill which has been devoted to it. The essential points to be attained are complete combustion of the oil with the highest possible flame temperature, and the avoidance of escape of unburned or partially burned oil. At the present time there is great difference of opinion as to the use of oil with a high or a low flashing point for general lighting purposes. As this is a controversial matter it has not been touched on here, but whatever may be the merits of the one or the other, it seems clear that it is a distinct advantage to have a lamp so constructed as to prevent access of flame to the interior of the reservoir, and that the latter should be metallic and of such a character that if it be thrown down or inverted the oil cannot escape.

A chapter has been introduced on that useful application of crude mineral oils for illuminating purposes, the Blast or Spray Lamp, of which the "lucigen" lamp is the type. The large volume of the flame, about 3 ft. long by 9 in. in diameter, renders it specially applicable for work carried on at night in the open air, to which use, moreover, it is almost exclusively confined by reason of the dull roar of the flame, and of the heat and smoke which it emits.

Several of the figures in this Section (V.) have been drawn for this article from lamps in the possession of Mr. Boverton Redwood, a few have been taken from Mr. Leopold Field's Cantor Lectures on Solid and Liquid Illuminating Agents, and a large number have been copied from the specifications of the patents referred to. Mr. Redwood has asked us to acknowledge the assistance given him by Mr. George T. Holloway in preparing the article on Lamps.

The use of OIL GAS is a curious instance of revival. In the early days of gas making it was used to a considerable extent, and is now again brought forward for the special purpose of lighting railway carriages and to some extent lighthouses; in both cases because it gives a light of high intensity with a small volume of gas.

The last Section—on MINERS' SAFETY LAMPS—by Messrs. Boverton Redwood and D. A. Louis, is not the least important. Our supply of coal depends on the efficiency of these appliances, and the numerous illustrations given will show how carefully they have been studied. Although many attempts have been made to secure the desired end by other means, the lamp almost universally used remains essentially the same in principle as that originally devised independently by Davy and by Stephenson. It is sad to think that the reckless carelessness of the men themselves, heedless of their own and their comrades' safety, is almost if not quite as great a difficulty to be overcome as the danger arising from the presence of explosive gases or coal dust. That, in short, as much study has to be devoted to devising means of preventing improper opening of the lamp, or deliberate injury to its structure, as to securing its efficiency as a safe light in an inflammable atmosphere. The importance of the special testing lamp devised by Dr. Clowes for readily and accurately ascertaining the amount of fire-damp present in the air of a mine, and the modification of it by Mr. Redwood for the special purpose of examining the air in the tanks of petroleum ships, will be readily understood and will be appreciated by all who know the difficulty of constructing an apparatus which, although delicate, can yet be used readily by men who are relatively unskilled. The authors of this Section wish to acknowledge their indebtedness to several works which have been consulted, including:—"The Report of the Commissioners on Accidents in Mines;" "The Transactions of the Federated Institution of Mining Engineers;" The Proceedings of the Royal Society, of the Chesterfield and Midland Institute of Engineers, of the South Wales Institute of Mining Engineers, of the South Staffordshire Institute of Mining Engineers; "The Journal of the Society of Arts," and "The Annales des Mines." Some of the figures have been borrowed from these sources, but a large number of them have been specially drawn for this article.

The Editors gladly express their indebtedness to the authors of the several articles, and also to many others who have contributed information or kindly allowed the use of illustrations. Among the latter they may mention Messrs. Rose, Downs, and Thompson; Price's Patent Candle Company, Limited; *Engineering;* and Mr. E. Cowles.

The very full and complete Index to this volume will, it is hoped, greatly increase its value as a work of reference.

The next volume of "Chemical Technology," Vol. III., will comprise Gas Lighting, Electric Lighting, Lighthouse Illumination, and Photometry; and, with Vol. II., will furnish a full and comprehensive account of the present state of "Lighting" in all its branches.

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LIGHTING.

INTRODUCTION.

As fuel, and its applications for the purpose of producing heat, are undoubtedly involved in some form or other in every one of the arts, and as it is the chief instrument in bringing about those changes which we usually class as chemical technology, the first volume of this series was naturally devoted to its consideration. This, the succeeding volume, treats of the application of fuel under such conditions as to furnish light, either directly or indirectly.

With certain small exceptions, to which reference will be made hereafter, the subject of lighting may be considered under two principal heads, one of which deals with the use of fuel to produce a gas which, on reacting chemically with another gas, will produce a temperature so high as to emit light, and the other in which fuel is used directly or indirectly to raise the temperature of a solid refractory body to incandescence. In the former case, the substances in the act of combination emit the light; in the other, the light is emitted by a highly heated but inert substance, and the source of heat may be non-luminous, or even, as in the electric light, entirely remote.

The most common illustration of the former class is that of a candle, but the phenomena even here are more complex than at first sight appears. The first stage is that the solid fatty matter of the candle is melted by the heat of the flame, and thus produces an *oil;* this is carried by capillary action up the wick to the highly heated region of the flame and there undergoes destructive distillation, from which result more or less complex gaseous hydrocarbons, and these in their turn undergo combustion, or, in other words, by the action of the oxygen of the air are converted into new compounds, this change being accompanied by the development of so much heat that the temperature is raised high enough to produce *light.* The candle is then on a small scale first an oil factory, and secondly a gas-works, the sole representative of mechanism being the wick.

If we consider the still more ancient use of a liquid oil in a lamp, we see that the later stages are still represented, the gas manufacture still taking place, and this may occur either with or without the assistance of a wick.

These operations, which occur simultaneously and on a minute scale in the candle, may be separated, both in time and space, and conducted on a scale of any desired magnitude and with apparatus of greater or less complexity, as when a liquid fuel is obtained from a solid, or a gas is produced from a solid or liquid fuel, and stored until it is required for use. The

intermediate products may be stored for any desired time, or transported from one spot to another as required, but the essential conditions remain the same.

In the recent application of "water gas" for illuminating purposes there is a somewhat greater complexity, but a similar result. By the action of carbon on water vapours at a high temperature, a mixture of combustible gases is obtained, which, burning in air, would produce a flame having very little luminosity, and so be useless for lighting purposes; but by the addition of a suitable volatile hydrocarbon the flame is rendered luminous, and the compound "gas" thus produced is, from our present point of view, not very dissimilar from coal gas.

There are other cases of illuminating gases, however, which have but little analogy with the candle. For example, a mixture of nitric oxide with the vapour of bisulphide of carbon when inflamed burns with an extremely brilliant luminous flame, but here the stages of oil and gas making are absent, or of an entirely different character.

The other class of cases in which light is obtained by the incandescence of a solid body is in all the higher developments of more recent date. The light given by a mass of heated metal or from a coke or charcoal fire is of course well known from all antiquity, but as a means of illumination of extremely limited use. It was not until oxygen was employed to produce a flame of extremely high temperature when uniting with hydrogen or coal gas, that any notable use of this method of lighting was made. The intense heat of this flame, itself practically non-luminous, was made to raise the temperature of a piece of solid lime until it emitted light of great brilliance, the lime remaining unchanged. Recently many other similar arrangements have been devised in which a non-luminous flame of sufficient intensity is made to impinge on a solid refractory and inert substance. The Welsbach light is now a familiar instance of this.

The electric light, whether from the electric arc or from an incandescent filament, is also of this character, although the necessary heat is not obtained directly from the combustion of fuel, but by interposing a place of high resistance in an electric circuit. In the arc light, this is an actual interruption of continuity of a carbon conductor, the ends of which, at the point where the current is compelled to leap across the gap, become heated to the very highest intensity. In the incandescent form the conductor is continuous, but at a suitable point the resistance is greatly increased either by the introduction of a different substance of less conducting power, or more generally by reducing the conductor to an extremely fine filament, which is usually of carbon, although other substances, such as platinum, or even a fine stream of mercury, have been used. For an incandescent light, the resistance offered to the current must be sufficient to produce great heat, but must not, of course, be so great as to prevent the passage of the current. To protect the carbon filament, it must be placed in a glass vessel from which the air has been exhausted, and if platinum be used the heat must not be allowed to reach the melting point of the metal. In the mercury lamp, the conductor is maintained in spite of the volatility of the metal by constant renewal from a reservoir.

The light of the highest intensity is not necessarily the most useful, and the selection of a source of light will depend chiefly on whether it is desired that the light itself should be seen, or whether it should be the means of rendering visible objects which are not themselves luminous. For the former purpose, in most cases, the more intense the light and the more nearly it approaches to a true point the better, as, for example, in the case of lighthouses, signal-lights of ships, railway signals, and the head-lights of railway trains. For these it is needful that the light itself should be seen clearly

and at a sufficient distance, but it is not necessary, or may be even a disadvantage, that any of the surrounding objects should be visible; the light is required merely to deliver its agreed message as a *signal*. It is rather singular that, as regards railway trains, there seems to be a difference in this respect between British and Continental practice, the former using small lamps merely as signals, and the latter large lamps with reflectors apparently for the purpose of illuminating the road in front. Possibly the latter is a survival from times still recent, when lower speed prevailed. At the speeds common in the former such illuminations would be useless, and perhaps even injurious, by reason of the surrounding glare interfering with ready sight of distant signals.

When, however, light is required for the purpose of being reflected from non-luminous objects, and so rendering them visible to the eye, it is desirable to have a large amount of light of low intensity, and generally that it should be distributed about the area to be lighted rather than concentrated at one or a few points. A room which would be well lighted by means of twenty candles will be but poorly lighted by means of a single lamp giving light equal to twenty candles. Moreover, if the flame of such a lamp be surrounded by an opal globe, or a white or opal shade and cup, it will be found that the room is better lighted than by the naked flame, although in all probability the globe or shade will intercept one half of the light. This may be further illustrated by the practice in some cases of workmen in the open air who carry on their labour without difficulty by the light from a brazier of glowing coals or coke, the actual light from which is very small, perhaps not exceeding that from a single candle, but if the candle were employed in place of the brazier it would be found quite inefficient. Generally it may be said that with a given amount of light, the lower and the more uniform the intensity the better the illumination. The reason for this must probably be sought in the structure of the eye, the iris of which adjusts itself continually to the amount of light falling upon the retina, so that no spot on this should receive an amount of light too great to be borne with comfort. The aperture of the iris is therefore adjusted not to the total amount of light entering the eye, but to the intensity of the brightest spot of the image on the retina, so that while this can be seen perfectly the aperture will be too small to allow sufficient light to enter to admit of clear vision of the remainder. If the illumination be uniform, that is, free from points of exceptional intensity, the amount of light allowed to enter the eye will be at a maximum.

SECTION I.

FATS AND OILS.

BY

WILLIAM Y. DENT.

The Fats.—These products of organic life derived from the structures of plants and animals are found very generally diffused in nature, and play a very important part in domestic economy, being largely consumed as food, and extensively employed in the production of light.

Their elementary constituents are carbon, hydrogen, and oxygen; the proportion of carbon being very large, in many instances as high as 80 per cent. The following table shows the relative proportions of carbon, hydrogen, and oxygen in some fatty substances employed for illuminating and other purposes.

Nature.	Carbon.	Hydrogen.	Oxygen.	Analyst.
	Per cent.	Per cent.	Per cent.	
Olive oil	77.21	13.36	9.43	Gay-Lussac & Thenard
Beeswax	81.80	12.67	5.53	" "
Sperm oil	78.90	10.97	10.13	Ure
Linseed oil	76.01	11.35	12.64	Saussure
Tallow (stearin)	79.00	11.70	9.30	Chevreul
Spermaceti	81.60	12.80	5.60	"

The several descriptions of fatty substances differ widely from each other as regards their consistency, some of them being solid at ordinary temperatures and others liquid. The solid fats are represented by the several varieties of tallow, as well as by some of the substances commonly known as waxes, such as Japan wax, and myrtle wax, which from their composition (consisting as they do of fatty acids in combination with glycerin) are not strictly speaking waxes, but should properly be classed with fats. The liquid fats are represented by the numerous varieties of oils which are ordinarily in a fluid condition; whilst between the solid and liquid fats there are others holding an intermediate position partaking of the character of grease, being more or less of a semi-solid consistency, such as palm oil and cocoa-nut oil.

The fats as obtained from natural sources, whether from the animal or vegetable kingdom, are not homogeneous chemical compounds, but consist of certain mixtures of proximate constituents, principally stearin, palmitin, and olein, in varying proportions; some of these, such as stearin (στέαρ, tallow) are solid at ordinary temperatures, whilst others are liquid, such as olein (ἐλαίον, oleum, oil), remaining fluid at as low a temperature as 0° C. (32°F.). The principal solid fatty constituent of mutton tallow was termed margarin (μάργαρον, a pearl) on account of the pearly lustre sometimes exhibited by the fatty acids of mutton tallow, or by some of their compounds.

Margarin was at one time considered to be a distinct kind of fat, but it has since been shown by Heintz to be a mixture of stearin and palmitin; the latter not only enters into the composition of animal fats, but (as the name indicates) is the principal constituent of palm oil.

The proximate constituents of fatty substances were found by the classical researches of Chevreul to consist of certain organic fatty acids, united with an organic radicle which from its sweet flavour received the name of glycerin (γλυκύς, sweet); it is, however, more consistent with modern chemical nomenclature to speak of it as glycerol, since it ranks chemically as an alcohol; it is in fact a trihydric alcohol represented by the formula $C_3H_5,(OH)_3$.

Stearin is an ethereal salt formed by the union of stearic acid, $C_{18}H_{36}O_2$, and glycerol with elimination of water; and similarly, palmitin is formed from palmitic acid, $C_{16}H_{32}O_2$, and glycerol; olein from oleic acid, $C_{18}H_{34}O_2$, and glycerol.

The true fats strictly speaking are all glycerides, and are distinguished from other compounds which they resemble in physical character, such as the various kinds of wax, by yielding glycerin or glycerol when subjected to any process of saponification.

The waxes when subjected to a process of saponification yield certain of the higher monhydric alcohols, which vary in their composition with the nature of the wax. Beeswax, as obtained from the honeycomb of various species of bee, may be considered to be the type of a true wax; it is composed of free cerotic acid, $C_{27}H_{54}O_2$, and myricin, which is a solid having the constitution of myricyl palmitate, $C_{16}H_{61}(C_{30}H_{31})O_2$, a derivative of myricyl alcohol, $C_{30}H_{61}.OH$. The true composition of beeswax was first determined by Brodie; more recently Hehner * has made a very complete investigation of the question of commercial waxes, and has devised a system of analysis which has been generally adopted.

There are a number of other waxes not made by bees, several of which are of commercial importance:—

Chinese wax, or Pe-la, the latter name being derived from the Chinese, chung-pĕh-lă, signifying insect white wax. This is produced by the action of an insect, *coccus pe-la* (somewhat resembling in appearance the small woodlouse) upon certain trees, more especially the *Fraxinus chinensis*, which is cultivated for the express purpose of producing the wax. The cocoons containing eggs are collected in April, folded in leaves, and attached to the tree; in from one to four weeks the insects emerge and spread over the branches, the bark of which they puncture; the young shoots soon become covered with a layer of wax, which is removed in August and melted, in order to separate it from dirt and insects. The wax is composed of cerotate of ceryl, melting at a temperature of 82° C. (180° F.); it is almost entirely consumed in China for illuminating purposes, very little reaching this country.

Carnauba Wax.—This is a yellowish brittle substance, and so hard as to have received the name of stone-wax. It adheres in a thin film to the leaves, stalks, and berries of a Brazilian palm, *Copernicia cerifera.*

It has a sp. gr. of 0.995 – 1.000 at 60° F. and of 0.842 at the temperature of boiling water. The melting point is very high, 83° – 85° C. (181° – 185° F.). It is of a complex composition, consisting chiefly of cerotic acid, myricyl alcohol, and myricyl cerotate. This stone-wax is frequently employed in the adulteration of beeswax, to counteract the softness and low melting point of some other adulterant.

Palm Wax.—This is also a very hard wax somewhat resembling carnauba, obtained from the bark of *Ceroxylon audicola*, from the Cordilleras of New Grenada. It melts at 72°–86° C. (162° – 187° F.).

* "Analyst," viii. 1883.

Spermaceti.—This is obtained from the cellular tissue in the enormous head of the cachalot or sperm whale (*Physeter macrocephalus*), and consists for the most part of cetyl palmitate, $C_{16}H_{31}.(C_{16}H_{33})O_2$, existing in the head as "sperm crystals"; these are also obtained from the body oil, after melting and cooling. On saponification, cetyl hydrate is liberated, but no glycerol.

SAPONIFICATION OF FATS.

Fats may be decomposed into their proximate constituents in several ways, to all of which the term saponification is applied, although strictly speaking it only properly belongs to that which consists in subjecting the fats to the action of a powerful base (such as soda or lime) which takes the place of the glycerol, combining with the fatty acids to form a true soap. If stearin be the substance acted on, a corresponding stearate of soda or stearate of calcium is produced, the glycerol being set free. This soda or lime soap, is subsequently decomposed by boiling with sulphuric acid, which acts on it, forming sodium or calcium sulphate, with liberation of stearic acid. The plan usually adopted on a large scale is to place in a lead-lined tank a quantity of tallow and palm oil, which is melted by passing steam into it; the proper proportion of slaked lime (the quantity depending on the nature of the fat) is then thrown in, and the mixture boiled for some hours with open steam; this causes the fatty acids to combine with the lime, forming a hard insoluble substance technically known as "rock," consisting of stearate, palmitate, and oleate of calcium, whilst the glycerol remains dissolved in the water, forming a very dilute solution commonly known as "sweet water." The calcium salts are subsequently boiled with sulphuric acid which decomposes them, forming calcium sulphate, whilst the liberated fatty acids float on the top of the liquid; when partially cooled, the melted fatty acids are run off into pans and allowed to solidify. The solid cakes are subsequently placed in horsehair bags and subjected (at a gentle heat) to hydraulic pressure, to force out the oleic acid. They are afterwards placed in stronger bags, and subjected to a higher pressure (approaching 6 tons on the square inch) at a temperature of 49° C. (120° F.). The pressed cakes, which consist of stearic and palmitic acids, when cast into blocks are then ready for the use of the candle manufacturer, or for other purposes.

These fatty acids are still known commercially by the name of stearin, or palmitin, although these terms properly represent the harder portions of tallow, or other fats as obtained by simply subjecting the fats to pressure, by which the harder portions or stearin and palmitin are separated from the more fluid portions, or olein.

The candles made from pressed fats were termed stearin to distinguish them from those made of tallow, but these have been now superseded in their turn by the so-called stearin candles of the present day, although these really consist of stearic and palmitic acids.

The fat can also be decomposed by a process to which the term acidification is applied, which consists in subjecting them to the action of strong sulphuric acid assisted by heat. The fats are placed in copper boilers with the acid, and are kept heated by steam at a temperature of about 176° C. (350° F.) for several hours. The glycerol of the fat is partly converted into sulphoglyceric acid, and partly decomposed with the disengagement of carbonic and sulphurous acids, a certain amount of carbon being deposited. The fatty acids combine with the sulphuric acid to form sulphostearic, sulphopalmitic, and sulpholeic acids. These are decomposed by the action of steam with the formation of stearic, palmitic, and oleic acids; the oleic acid is at the same time partially converted into elaïdic acid, which has the same composition as oleic acid, but differs from it as regards its physical properties, being much

less fusible, its melting point being about 45° C. (113° F.). The formation of this elaïdic acid tends to increase the amount of solid fatty acids obtained by this method of treatment. The black mass (consisting mainly of fatty acids), after washing from the sulphuric acid and sulphoglyceric acid, is transferred to a retort, and the fatty acids distilled over by means of superheated steam assisted by a gentle "bottom heat."

The earlier products of the distillation consist of hydrocarbons, some of which are in a gaseous and others in a liquid condition. The fatty acids that come over are of a good colour, melting at 42°–44° C. (108°–112° F.); and when subjected in bags to pressure so as to separate the more fluid oleic acid, a hard solid stearic acid is obtained, melting at 49°–50° C. (120°–122° F.).

The acidification process is extensively applied to palm and cocoa-nut oils, and is especially adapted for decomposing bone oil, as well as refuse fats of every description, and converting them to useful purposes.

In 1854, a patent was taken out by Tilghmann for decomposing fats by exposing them in a long wrought-iron vessel (lined with lead and placed in a horizontal position) to the action of water at a high temperature and under great pressure. This was subsequently superseded by the autoclave process of De Milly, in which the fat was put into a boiler (made of stout copper, provided with a stirrer, and placed in a vertical position), together with one-third its volume of water and a small quantity of lime (about 2 per cent.), or its equivalent of caustic soda. The boiler was then heated for three or four hours under a pressure of 120 lbs. to the square inch. Very large quantities of stearic acid are made by means of this process.

In 1855, Mr. G. F. Wilson, of Price's Patent Candle Company, effected the decomposition of fats by subjecting them to the action of superheated steam under ordinary pressure. By passing steam at a temperature of 313° C. (600° F.) through the fats, the fatty acids are separated from the glycerol and are distilled over, the glycerol condensing in the receiver, and forming a dilute aqueous solution below the layer of fatty acids. By concentrating this dilute solution glycerol is obtained, free from the alkaline salts with which it had always (previously to the discovery of this process) been contaminated; when redistilled by the aid of steam a glycerol of chemical purity is obtained, which under the name of "Price's glycerin" has for many years proved a valuable article for the manufacture of pharmaceutical preparations, and for various medical purposes.

The fatty oils employed for illuminating purposes, when exposed to the influence of heat do not evaporate, and are therefore termed fixed oils, to distinguish them from the volatile or essential oils, such as turpentine, from which they differ both as regards their composition and properties, the latter evolving, at ordinary temperatures, a distinctive and frequently an agreeable odour. The fixed oils, when raised to a high temperature under ordinary atmospheric pressure, decompose, and are resolved into a great number of new products, some of which are of a very offensive description. The glycerol, one of the constituents, is partly converted into acrolein or acraldehyde, a compound of an extremely pungent character; it is this substance which gives rise to the peculiar and very unpleasant odour produced on blowing out a candle made from tallow or any fat containing glycerol. It is also from acrolein that the vapours arising from boiling oil derive their well-known characteristic and very irritating properties. The fatty acids of the oil are partly volatilised, and partly undergo conversion into hydrocarbons (especially of the olefine class), carbonic acid, and other products, a considerable quantity of carbon being left as a residue; part of the oleic acid is also converted into sebacic acid.

When these fatty substances are passed through a red-hot tube they are almost entirely decomposed into volatile products, consisting principally of carbonic acid and various hydrocarbons.

Refuse fat, and some of the cheaper of the fixed oils, were at one time converted into gaseous hydrocarbons and used for illuminating purposes, under the name of oil-gas, but they are now but little utilised in this manner, cheaper sources of light, such as are afforded by the mineral oils, having been substituted for them.

The fixed oils may be divided into two classes, drying and non-drying oils, although no sharp line of distinction can be drawn between them. The drying oils, as represented by linseed, hempseed, and poppy-seed oils, on exposure to air in thin films absorb oxygen, and in a short time become converted into a hard resinous substance, a property which renders them particularly valuable for the purposes of the painter and varnish-maker. The non-drying oils, as represented by olive-oil, under similar circumstances remain liquid, whilst some of the other oils, such as cotton-seed oil, hold an intermediate position in this respect.

The non-drying oils, on exposure to the air, become rancid by the absorption of oxygen, acquiring a very unpleasant flavour and disagreeable odour, of which we have a familiar example in the case of salad oil after it has been kept for a long time in a partially filled bottle; but fats containing caproic and caprylic acids, such as cocoa-nut oil and butter fats, are peculiarly liable to undergo this change; the drying oils, on the contrary, exhibit much less tendency to alterations of this character.

This rancidity is due to fermentation, which is promoted by the action of the oxygen of the air on the albumenoid and other impurities contained in the oils, so that a well-refined oil is less liable to undergo a change of this nature than one containing a larger proportion of impurities. As the action progresses, the neutral fats are decomposed, the fatty acids being set free and glycerol produced; some of these fatty acids, more especially those emanating from cocoa-nut oil, evolving an exceptionally unpleasant odour. By agitating a rancid oil with boiling water, and subsequently washing it with a weak solution of soda, it may be deprived of its rancidity, and again made to resume the condition of a sweet oil.

This absorption of oxygen by oils, more especially by drying oils, is attended with the development of heat, and to such an extent is this the case, that cotton-waste or other porous material containing oil, when laid in a heap is liable to become ignited, and it has been proved that many serious fires have been caused by such ignition. The danger of fire arising from this source has been so completely established by the experiments of Gellatly and others, and is now so well known and so generally recognised, that manufacturers are very careful not to allow any accumulation of oily cotton- or silk-waste to remain on their premises. The absorption of oxygen by oil is now conducted on an extensive scale for the purpose of thickening it, with the object of producing what is known as oxidised or "blown" oil. The oils generally operated on are rape, cotton-seed, and linseed. The oil is heated, starting at a temperature of about 70° C. (158° F.), and air is then blown through it by means of a perforated tube for from sixteen to thirty hours; the heat generated by the chemical action which takes place is sufficient to maintain the temperature, which is not, however, allowed to rise above 75° C. (167° F.). The proportion of oxygen in the oil is considerably increased by this treatment, being in some samples more than doubled. Rape oil can be made to acquire the consistency of castor oil, its sp. gr. ranging from 0.942 to 0.971; this thickened oil is used for the purpose of increasing the viscosity of lubricating oils; it is capable of being mixed with mineral oil in much larger proportions than castor oil without the risk of any subsequent separation taking place. Linseed oil can be converted into a semi solid glutinous mass capable of being used in the manufacture of rubber substitute as well as for a variety of other purposes.

The expansion that takes place in the volume of oil by increase of

temperature is so considerable as to make it necessary for commercial purposes that the amount of such expansion should be known. According to the determinations of Preisser, olive oil increases in volume for each degree Centigrade $\frac{1}{1200}$, rape oil $\frac{1}{1120}$, and train oil $\frac{1}{1000}$, so that 100 measures of train oil at 0° C. (32° F.) become 102 measures at a temperature of 20° C. (68° F.). More recent determinations of the density of oils at different temperatures have led to the following results as stated by Allen. In order to ascertain the rate of expansion of an oil, the density should be taken at two different temperatures which should be as far apart as practicable. The temperatures adopted were 15.5° C. (60° F.), and 98°–99° C. (208°–210° F.) as most closely representing the actual temperature of an oil when immersed in a vessel of boiling water. The density of rape oil was found to be at these temperatures 0.915 and 0.863, water at 60° F. being represented by 1.000; and from a number of experiments with different oils, including olive, rape, sesame, arachis, cotton-seed, and linseed, it was found that for these oils 0.00064 might be adopted as the figure representing the correction in density required by them for each degree Centigrade, or 0.00035 for each degree Fahrenheit variation in temperature.

TESTING OILS.

The tests that are capable of being applied for ascertaining the quality and purity of oils, as well as of fatty substances generally, are of two kinds, some of them being of a physical, and others of a chemical nature. Until within the last ten or twelve years, these tests were of a somewhat empirical character, the knowledge that we possessed of the constitution of the various descriptions of fatty substances not being sufficient to allow of such an examination as would afford an insight into their composition and character.

Many of the methods of testing oils adopted in the trade (however crude some of them may appear to be) are unquestionably of much service as preliminary tests in detecting adulteration. The amount of information that may be gained by making a proper use of the senses of taste and smell, when educated by experience, is much greater than is frequently supposed. The odour given off on warming will often serve to detect the presence of even small quantities of animal oil, when mixed with those of vegetable origin, as well as to distinguish its nature; whilst the very peculiar aftertaste left by mineral and rosin oil at the back of the throat constitutes a very delicate test for either of these oils. The peculiar odour developed by some oils may also be rendered more readily perceptible by rubbing a small quantity in the palms of the hands, or by igniting the oil, blowing out the flame, and noting the character of the vapours given off.

A series of tests have, however, within the last few years been elaborated of a much more searching and scientific character, the system of examination now generally adopted for ascertaining the quality and purity of fatty substances involving a series of determinations with reference to the following points :—

Specific Gravity at definite temperatures of the fat.

Do. do. of the fatty acids obtained by saponification.

Melting and Solidifying Points of the fats.

Do. do. of the fatty acids.

Viscosity.—Time required to pass through an orifice of a definite size, and at a known temperature and pressure.

Acidity.—Estimation of the amount of free organic acid.

Saponification.—Amount of alkali required for complete saponification of the oil.

Maumené's Temperature Reaction.—Rise of temperature observed on mixing with concentrated sulphuric acid.

Elaïdin Reaction.—Effect produced by nitrous acid.

Bromide and Iodine Absorption.—Quantity absorbed under conditions that prevent the formation of substitution products.

Behaviour with solvents.

Colour Reactions produced by acids, alkalies, and other reagents.

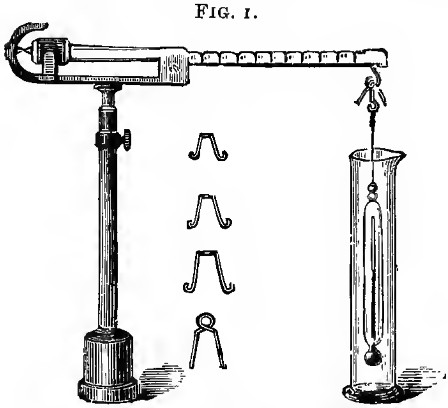
Cohesion Figures formed by placing a drop of oil upon water.

Absorption Spectra.—Spectroscopic observation of absorption bands.

Exposure to Air.—Observation of drying properties.

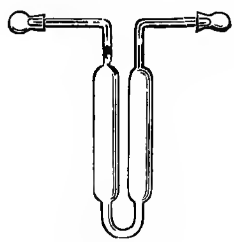
Specific Gravity.—The density of an oil has always been considered to be a matter of importance, as giving indications of its quality; but the manner in which this point is frequently determined for commercial purposes can scarcely be regarded as satisfactory. The attention paid to slight alterations in the temperature of the sample is insufficient, a point which (owing to the high coefficient of expansion of oils by heat) it is highly necessary should be carefully observed. The oleometer sometimes employed is often graduated in an arbitrary manner that does not tend to promote exactness in the observations made, and has but little pretensions to scientific accuracy. If a sample of oil which is fluid under ordinary circumstances, be carefully brought to a temperature of 15.5° C. (60° F.) by immersing the hydrometer tube containing it, in water at that temperature, results of a very trustworthy character may be obtained by means of an ordinary

FIG. 1.



Westphal's Hydrostatic Balance.

FIG. 2.



Sprengel Tube.

hydrometer, provided that the accuracy of the instrument has been previously tested. Greater reliance can, however, be placed on results obtained by the use of a specific gravity bottle, the density being determined by actual weight. This is also the case when Westphal's hydrostatic balance, Fig. 1, is employed, which consists of a counterpoised thermometer or plummet suspended to the beam. On immersing the plummet in any liquid, the loss of weight is ascertained by adjusting riders until equilibrium is restored. With such fats as are ordinarily of a solid or semi-solid consistency, it is necessary to take the density at a high temperature; that at which water boils at the place where the laboratory is situated being generally adopted. For this purpose a Westphal's hydrostatic balance may be employed, or a Sprengel tube, which consists of an elongated **U**-tube of glass, Fig. 2, terminating in two capillary tubes bent at right angles in opposite directions and protected by caps. The tube filled with the oil to be tested is immersed in a vessel of water kept at the desired temperature. When the oil has acquired the same temperature as the water, the quantity is adjusted so that it fills the tube from the extreme point of one capillary tube to a mark on the other capillary.

The following results were obtained by Allen, water at 15.5° C. (60° F.) being represented by 1000 :—

Nature of Oil or Fat.	At 15.5° C. (60° F.)		98°–99° C. (208.4°–210.2° F.)
Rape oil	915.0	...	863.2
Cotton-seed oil	925.0	...	872.5
Castor oil	965.5	...	909.6
Sperm oil	883.7	...	830.3
	At 50° C. (122° F.)		98° C.
Tallow	895.0	...	862.6
	At 40° C. (104° F.)		
Lard	898.5	...	860.8
	At 60° C. (140° F.)		
Japan wax	901.8	...	875.5

The densities of the fluid oils can be compared with those of a more solid character by taking the density of the latter at a temperature at which they are liquid, and again at the boiling point of water.

The densities of solid fats or waxes may also be determined by dropping small fragments or globules (obtained by allowing small particles of the melted material to cool very slowly) into dilute alcohol at a temperature of 15.5° C. (60° F.), the strength of which is so adjusted that the globules remain in equilibrium in any part of the liquid. The density of the fat is determined by taking that of the liquid. The samples of solid fat should be deprived of any water or suspended matter they may contain, by keeping them melted for a short time at as low a temperature as possible, and filtering through dry paper.

The estimation of the sp. gr. of the fatty acids obtained by the saponification of samples of the fat under examination is of great assistance in determining the nature of the fat, the difference in the sp. gr. of the fatty acids being frequently of a more definite character than that of the fats from which they have been obtained.

The following table shows the sp. gr. of a series of oils, and also of their fatty acids as determined by Allen, water at 15.5° C. (60° F.) being represented by 1000.

	Oils.		Fatty Acids.	
	At 15.5° C. (60° F.)	98°–99° C. (208°–210° F.)	15.5° C.	98°–99° C.
Olive oil	914–917	—	solid	843.0
Rape oil	915.0	863.2	solid	843.8
Linseed oil	935.0	880.9	923.3	861.2
Cotton-seed oil	925.0	872.5	solid	846.7
Arachis oil	922.0	867.3	solid	846.0
Castor oil	965.5	909.6	950.9	896.0

Melting and Solidifying Points.—The melting points of the solid fats, as pointed out by Duffy, vary to some extent with age, the amount of free acid they contain, and the circumstances under which they are submitted to the influence of heat. If a fat be subjected for any length of time to a degree of heat considerably above its melting point and then allowed to cool, the temperature at which it again assumes a liquid condition will be appreciably lower than would otherwise be the case. A method very generally adopted for ascertaining what is termed commercially the melting point, but which is, more correctly speaking, the solidifying point of fats, is to put the melted sample into a warm beaker, or test tube, and stir the contents slowly with a thermometer (previously warmed), taking care that the bulb of the thermometer is completely immersed in the melted fat. When

the fat begins to solidify, the thermometer is closely watched until it ceases to rise, and remains stationary for one or two minutes, when the temperature observed is registered as the melting point of the fat, or wax. Sometimes a mean is struck between the temperature at which the fat begins to melt and its solidifying point, the figure thus obtained being taken as the melting point.

Great accuracy could scarcely be expected from a method which requires some experience to obtain a constant number, and it is not surprising that the results obtained by different observers exhibit an appreciable variation, often amounting to more than 1° F.

A rapid and more satisfactory method of ascertaining the melting point of fats and waxes for commercial purposes is to melt a sample in a test tube, and pour out the mass, leaving only a thin film covering the lower portion of the tube. The tube when cold is placed in a vessel of water, the temperature of which is some degrees below the melting point of the fat. The water is then very gently heated with constant stirring, and as soon as the fat begins to run down the sides of the tube, the temperature is noted, and taken as that of the melting point of the fat. If the fat or wax is a mixture of several kinds, having different melting points, the temperature at which it is completely melted, as well as that at which it begins to run, is noted. This method has the advantage of allowing several samples to be examined at the same time, and under precisely similar circumstances, each test tube being removed from the bath as soon as the fat begins to melt. The results obtained in this manner when comparing two samples of fat, are so sharply defined that no doubt can arise as to which of the samples has the higher melting point.

Rudorff covers a thermometer bulb with a layer of the fat and immerses it in water, which is very gradually warmed, and the point at which the fat leaves the bulb and begins to ascend through the water is noted.

The following is stated by Allen to yield very satisfactory results. The substance is melted at a temperature slightly above its fusing point, and whilst in a molten condition is drawn up into a very narrow glass tube (made by drawing out one end of a piece of ordinary quill tubing), in which it is allowed to solidify spontaneously. After an interval of not less than an hour, the tube (open at both ends) is attached by means of a cork, or of an india-rubber ring, to the stem of a thermometer in such a manner that the part of the tube containing the substance the melting point of which is to be ascertained, shall be at the same level as, and in close proximity to, the bulb. The thermometer, with the tube attached to it, is then immersed in water, which is gradually heated (at a rate not exceeding 0.5° C. per minute) until fusion of the contents of the capillary tube takes place, when the temperature is recorded. The source of heat is then removed, and the temperature at which the fat resolidifies is observed. In cases in which the melting and solidifying are not notably different, it is not unusual to record the mean of the two observations as the real melting point. It is advisable to immerse the beaker of water containing the thermometer in an outer vessel also filled with water, and to apply the source of heat to the latter.

Bensemann,* in taking the melting point of fatty acids, places a drop of the previously fused material in the wide portion of a tube drawn out very fine at one end. The tube is then placed in a beaker of water which is very slowly warmed until the fatty acids begin to flow down the sides of the tube, when the temperature is observed. This is termed the initial point of fusion. The heating is continued until the last trace of turbidity disappears, when the temperature is again noted, the latter being termed the concluding point of fusion. He states that the two points are easily distinguishable, and that there is frequently a difference of 3°–4° C. between them. With fats, the

* "Jour. Soc. Chem. Ind.," iv. 535 [1885].

concluding point of fusion is less clearly marked than is the case with fatty acids, and in examining the former he considers that the initial point only need be registered.

The determination of the melting point of fatty acids is in many cases of important service in detecting the presence of the oils from which they have been derived. The melting point of the fatty acids from cotton-seed oil, for example, serves to point out a marked distinction between this oil and several of the other vegetable oils which are liquid at ordinary temperatures, as will be seen by the following table.

Melting point of the fatty acids obtained from the under-mentioned oils as determined by Hübl.

Nature of Oil.	Cent.		Fah.
Castor oil	13.0°	...	55.4°
Linseed oil . . .	17.0°	...	62.6°
Hempseed oil . . .	19.0°	...	66.2°
Rape oil	20.1°	...	68.2°
Poppy oil	20.5°	...	68.9°
Olive oil	26.0°	...	78.8°
Cotton-seed oil . . .	37.7°	...	99.8°

For taking the melting point of fatty acids, Archbutt considers the method described by Bach to be the most satisfactory. This consists in introducing some of the fatty acids into a narrow test tube, and allowing them to solidify. Heat is then gradually applied by means of a water bath, and the temperature noted at which the liquid fatty acids become perfectly transparent. The melted acids are then allowed to cool, and the temperature noted at which a cloud begins to form.

Viscosity.—This is determined by ascertaining the time occupied by a known weight or measure of oil in passing through an orifice of a definite size, at a known temperature, and under a uniform pressure, as compared with a given standard, for which rape oil is sometimes taken, but more commonly water, or glycerin. This test applies more particularly to lubricating oils and is fully described under the head of Petroleum Oils.

Acidity.—The determination of the amount of acidity in oils, is a question of great importance, inasmuch as, when used for lubricating purposes, it causes them to act rapidly on metals, and when used for burning in lamps, it promotes the charring of the wick. Archbutt considers that an olive oil containing more than about 4 per cent. of free fatty acids cannot be regarded as suitable for lamps. Acidity in a sample of oil may in some cases arise from the oil not having been sufficiently washed from the mineral acid (sulphuric or hydrochloric) used in the process of refining; this may be ascertained by agitating the oil with warm water, separating the latter and testing it with a solution of methyl orange, which will produce an orange or red coloration if any mineral acid be present. The acidity due to the presence of free fatty acids, arising from the decomposition of the oil by the action of the air, or from other causes, producing what is termed rancidity, cannot be estimated in this way, since the fatty acids of the fixed oils are for the most part insoluble in water. Samples of oil were formerly tested for acidity by observing the action they exerted on brass, or copper turnings, and no successful attempt appears to have been made to determine the actual amount of such acidity prior to 1881, when Hausmann showed the practicability of estimating the free fatty acids in an alcoholic solution of the oil, in the presence of glycerides. In estimating this acidity, a weak alcoholic solution of phenolphthalein is employed as indicator, any free acid that this solution might contain having been previously neutralised by the addition of a few drops of a solution of caustic potash, until a purple colour was produced. About five or six grams of the oil or fat to be tested is introduced into a flask, or beaker, with about 50 c.c. of strong alcohol and

heated to boiling for a few minutes in a water bath. Before pouring the alcohol on to the oil or fat, a few drops of the phenolphthalein solution should be added to the alcohol, and the liquid made of a faintly purple colour (if not so already) by a drop or two of standard solution of alkali. If the oil contains free acid, the colour disappears at once, and semi-normal solution of caustic potash is slowly added with continual rotation of the flask, or beaker, until the purple colour is restored. This purple tint will not remain for any length of time, gradually disappearing, owing to the action of the excess of alkali on the glycerides. It is necessary that the titration should be carefully made on account of the high combining equivalents of the fatty acids; the mean of the equivalents of palmitic acid (256), stearic acid (284), and oleic acid (282), being 274, or about five times the equivalent of potash (KOH). In order to avoid the trouble and labour involved, in calculating the total amount of fatty acid existing as such, or contained in the fat united with glycerol, from the saponification equivalent, this is generally represented by the amount of caustic potash (KOH) required to neutralise it, which is equally useful and enables a more direct comparison to be made between the results arrived at by different observers, and also between fats consisting of different fatty acids. The potash numbers obtained may be readily converted into those which represent fatty acids with tolerable accuracy, by multiplying by a factor, obtained by dividing the combining equivalents of the fatty acids by that of potash. In the case of tallow which consists of the glycerides of palmitic, stearic, and oleic acids, this factor is represented by the figure 5, and in the case of rape oil, the combining equivalent of the fatty acids of which is exceptionally high, the factor would be larger. If soda be the alkali employed in the saponification of the fats, the numbers arrived at can easily be converted into terms of KOH so as to secure uniformity in comparing the results of different experiments.

The following table shows the amount of free fatty acids generally found in commercial oils and fats, including some determinations in samples in which the acidity was exceptionally high.

Nature of Oil or Fat.	No of Samples examd.	Percentage of KOH required for neutralising free fatty acid.			Free Fatty Acid. Per cent.	Observer.
		Max.	Min.	Mean.		
Tallow, Russian . .	11	2.44	0.43	1.23	6.15	Deering
„ Australian .	36	(Fatty acids ranged from)			1.2–4.7	Tate
„ „ beef .	4	1.77	0.35	0.89	4.45	Deering
„ „ mutton	5	1.43	0.17	0.78	3.90	„
„ Town	2	1.38	0.91	1.14	5.70	„
„ „ (6 yrs. old)	1	—	—	5.00	25.00	„
Rape-seed oil . .	9	1.31	0.21	0.56	3.20	„
„ „ * . .	49	5.5	1.7	—	2.95	Archbutt
Linseed oil . .	5	0.32	0.15	0.24	1.30	Deering
„ „ boiled .	2	1.59	0.93	1.26	6.5	„
Cotton-seed oil . .	3	0.14	0.03	0.10	.5	„
Olive oil, Lucca . .	3	0.82	0.58	0.67	3.2	„
„ „ . .	1	—	—	4.21	20.2	„
„ Seville* .	32	10.0	1.5	—	4.4	Archbutt
„ Malaga .	35	25.1	2.0	—	6.7	„
„ Gallipoli .	19	16.9	0.9	—	7.3	„
„ Gioja . .	12	25.2	4.1	—	10.9	„
„ Messina .	28	16.6	0.5	—	9.1	„

Most of the above samples were taken from bulk representing very large deliveries.

* Free fatty acids calculated as oleic acid.

Saponification.—Amount of KOH required for complete saponification of the oil or fat. The determination of the total amount of potash required is most conveniently made at the same time as the estimation of acidity, in continuation of the process already described, the operation being carried out in a flask. After neutralising the free acid present, the semi-normal ($N/_2$) alcoholic solution of potash is added in considerable excess, 50 c.c. being run into the flask, to which is attached a reflux condenser; the alcoholic liquid is then boiled for an hour by means of a water bath, and the excess of potash used, beyond that required for the saponification of the fat, is ascertained, by titrating back with normal sulphuric acid. The percentage of potash required for the complete saponification of various oils, and fats, has been determined by a number of chemists, the results obtained agreeing in most cases pretty closely. Archbutt has found as the result of the examination of about 300 samples of olive oil that the potash number for this oil varies from about 18.8 to 19.2 per cent., and that in the case of rape oil from the examination of upwards of 50 samples that it varies from about 17.0 to 17.6 per cent. The samples examined represented large deliveries of oil selected as genuine, and received at different seasons of the year. The numbers given for cotton-seed oil vary from 19.1 to 19.6 per cent. and for linseed oil from 18.7 to 19.5 per cent.

By the saponification of a sample of oil or fat, on a considerably larger scale than that above described, followed by distilling off the alcohol and dissolving the soap formed in water, admixture with mineral oil may be detected, and the amount of the adulterant estimated, by determining the quantity of oil unacted upon by the alkali. The refining of petroleum oils is now carried out to such perfection, that they are not only completely "debloomed," but they are also in some cases deprived of the characteristic odour and flavour by which the ordinary refined oils are capable of being readily distinguished.

By the saponification of neutral fats, the fatty acids which they contain can be isolated and examined, and these in many cases exhibit points of difference of a more marked character than the fats from which they have been obtained. The amount of glycerol which the neutral fat yields on decomposition, can also be determined if necessary. The determination of glycerol is a matter of some little difficulty on account of the volatility of a concentrated solution at the temperature of boiling water, although Hehner has shown that a 50 per cent. solution kept at this temperature for two hours scarcely sustains any loss in weight. Various methods have at different times been proposed for the determination of glycerol. Of these it will be sufficient to mention three: The permanganate method originally proposed by Fox and Wanklyn, and subsequently modified by Benedikt and Zsigmondi, which depends on the oxidation of the glycerol to oxalic acid in an alkaline solution, by means of potassium or sodium permanganate. This method was abandoned by Benedikt in favour of the acetin process, devised by Benedikt and Cantor, which depends on the conversion of the glycerol into triacetin, by subjecting it to the action of acetic anhydride The product of the reaction is dissolved in a small quantity of warm water, the solution cooled, and the free acetic acid in the cold liquid is neutralised by a weak solution of caustic soda (2–3 per cent.); the triacetin is then saponified by boiling the solution for ten minutes with a standard 10 per cent. solution of caustic soda, the excess of alkali added being titrated back with normal acid. Lastly, the dichromate method as devised by Hehner,* which consists in quantitatively oxidising the glycerol to carbonic acid by treatment with a standard solution of potassium dichromate and sulphuric acid, the exact oxidising value of which has been previously ascertained. About 3 grams

* "Jour. Soc. Chem. Ind.," viii. p. 7 [1889].

of the fat in which the glycerol is to be determined is saponified in the usual manner, with alcoholic solution of potash; the resulting alcoholic soap solution is diluted to about 200 c.c., and the soap decomposed by the addition of sulphuric acid. The fatty acids are filtered off, and the filtrate containing the glycerol and washings (amounting to about 500 c.c.) is vigorously boiled down in a covered beaker to one-half its bulk, and the glycerol determined volumetrically by adding sulphuric acid and standardised solution of dichromate.

It is of course obvious that such a method cannot give accurate results unless the glycerol is free from impurities capable of being oxidised by the potassium dichromate.

The quantity of glycerol usually contained in oils and fats is shown by the following numbers:—

Nature of Fat or Oil.	Glycerol, per cent.	Observer.
Olive oil . . .	10.26 ...	Hehner
„ . . .	10.1–11.4 ...	Benedikt & Zsigmondi
Tallow . . .	9.9–10.0 ...	„ „
Cocoa-nut oil . .	13.3–14.5 ...	„ „
Linseed oil . . .	9.4–10.0 ...	„ „
„ . .	10.24 ...	Hehner
„ . .	9.39 ...	Allen
Castor oil . . .	9.13 ...	„
Northern whale oil .	11.96 ...	„
Japan wax . . .	11.6–14.7 ...	„
„ . .	10.3–11.2 ...	Benedikt & Zsigmondi
Myrtle wax . .	13.38 ...	Allen

The amount of glycerol recoverable by soap manufacturers is stated to be not more than 7–8 per cent.

Maumené's Temperature Reaction is based upon the rise of temperature which takes place when an oil is mixed with concentrated sulphuric acid. The most approved method of carrying out this test is to weigh out 50 grams of the oil into a tall beaker of about 7 ozs. capacity, which is then immersed in water (say at about 15°–20° C.; 60°–68° F.) until the oil has acquired the same temperature, when the beaker is taken out, wiped dry, and dropped into a nest of cotton-wool, previously prepared for it, in a wider beaker or other receptacle. A reading of the thermometer immersed in the oil having been taken, 10 c.c. of sulphuric acid of a sp. gr. of 1.844, containing not less than 97 per cent. of real acid (H_2SO_4), and of the same temperature, is allowed slowly to run into the oil, the time occupied being about one minute. The mixture is well stirred all the time with the thermometer, so as to incorporate the oil and acid as perfectly as possible during the addition of the acid, and subsequently, so long as the temperature continues to rise, the highest point reached being noted.

In order to obtain unform results, it is essential that the mode of operating should be strictly adhered to in every particular, slight deviations which might be regarded as of no importance having been found to give rise to notable differences in the results. It is advisable in carrying out a number of experiments, to include in the series an oil known to be genuine, and capable of being used as a standard for comparison with others of unknown quality.

The following determinations show the rise of temperature that may be expected to take place:—

Rise of Temperature in degrees Centigrade.

Nature of Oil.			Observer.
Olive oil	40°–45°	...	Archbutt
"	42°	...	Maumené
"	41°–43°	...	Allen
Cotton-seed oil, refined	74°–75°	...	"
" "	77°	...	Baynes
" "	67°–75°	...	Maumené
Niger-seed oil	81°–82°	...	"
" "	81°	...	Allen
" "	82°	...	Baynes
Linseed oil	103°	...	Maumené
"	104°–111°	..	Allen
Rape oil	57°–58°	...	Maumené
"	58°–62°	...	Archbutt
"	51°–60°	...	Allen
"	54°–60°	...	Dobb
Lard oil	41°	...	Allen
Tallow oil	41°–44°	...	Maumené
Hempseed oil	98°	...	"
Arachis oil	67°	...	"
Sesame oil	68°	...	"
Walnut oil	101°	...	"
Poppy-seed oil	86°–88°	...	"

It is obvious from the above determinations, that the difference in the rise of temperature observed with several of the above-mentioned oils is sufficiently wide to afford valuable information in the examination of mixed oils.

Exposure of olive oil to sunlight was stated by Moschini many years ago to interfere with this test, as regards this particular oil. Archbutt has made some valuable remarks regarding this test in his paper on oils published in "The Journal of the Society of Chemical Industry," vol. v. p. 303 [1886].

Elaïdin Reaction.—This test was applied by Poutet so far back as 1819, for the detection of adulteration in olive oil, and is based upon the fact that olein, when subjected to the action of nitrous acid gas, is converted into elaïdin, an isomeric modification, solid at the ordinary temperature. The reagent employed depends on the power possessed by a solution of mercurous nitrate in nitric acid, of retaining nitrous acid, and is prepared by dissolving 6 parts by weight of mercury in 7½ parts of nitric acid, sp. gr. 1.35, without application of heat. One part by weight of this solution is shaken up with 12 parts of the oil, and the agitation repeated every ten minutes for two hours; the bottle containing the mixture is then put in a cool place for twenty-four hours, when the consistency of the mass is noted, and found to be in the case of genuine olive oil hard and solid. Boudet in 1832 showed that the active principle of this reagent was nitrous acid. The solution, when freshly made, is bluish green, but rapidly undergoes changes that destroy its activity. But little appears to have been done as regards the application of this test until quite recently, when the subject was investigated by Archbutt, who found that by employing nitric acid of 1.42 sp. gr. a reagent could be obtained which could be kept for several days, and yielded more constant results. It is prepared by dissolving 1 c.c. of mercury in 12 c.c. of cold nitric acid. Of this green solution, 2 c.c. are shaken up in a wide-mouth stoppered bottle with 50 c.c. of the oil to be tested, the mixture being agitated every ten minutes for two hours, or until solidification takes place. The bottle containing the mixture is set aside for sixteen hours, when the hardness of the elaïdin is tested by pressure with a glass rod. A genuine olive oil gives a lemon-coloured elaïdin of so firm a character as to resist the pressure of the glass rod. Lard oil and almond oil also yield a hard elaïdin,

but linseed, hempseed, walnut, and other drying oils remain in a more or less fluid condition, whilst the intermediate products yielded by several other descriptions of oil are of various degrees of consistency. After twenty-four hours at 10° C. (50° F.), arachis, niger-seed, cotton-seed, and sesame oils give orange-coloured products, whilst cod-liver oil and menhaden oil give red products of varying degrees of fluidity.

Bromine and Iodine Absorption.—The suggestion to make use of the absorptive powers of oils and fats for bromine, as a means of examining into their constitution, was made more than thirty years ago by Cailletet, who proposed to employ an alcoholic solution of bromine and an alcoholic solution of turpentine, the strength of which in terms of the bromine solution had been determined. An aqueous solution of potash was added to the oil, and then an excess of the bromine solution, the amount of bromine not absorbed being estimated by means of the turpentine solution. Such a method was open to very serious objections, arising from the rapid changes which must occur in the alcoholic bromine solution, and from the liability of the oil to oxidation and bromination; whereas no part of the absorption should be due to the formation of substitution products. In 1883, Mills and Snodgrass proposed to employ carbon bisulphide as the common solvent of the bromine as well as of the oil or fat, by which a more permanent solution of bromine was obtained as well as the further great advantage of securing as far as possible the absence of water, and very satisfactory results were obtained by their method.

The oil or fat having been first dried, either by heat or by filtration through dry paper, was dissolved in the bisulphide so as to make a solution of 10 per cent. or somewhat less strength.

A definite volume of this solution was then placed in a narrow-mouth stoppered bottle of 100 c.c. capacity, and diluted with more bisulphide solution to about 50 c.c. A decinormal solution of bromine in carbon bisulphide was then run in gradually and in successive portions, with agitation, until the colour of free bromine remained permanent for a quarter of an hour, exposure to direct sunlight being carefully avoided. To a similar bottle containing 50 c.c. of carbon bisulphide, standard solution of bromine was added until the tint in both bottles was the same. The quantity of bromine added in this blank experiment is deducted from that required in the absorption experiments.

In order to avoid the necessity of employing such an inconvenient solvent as carbon bisulphide, Mills subsequently adopted carbon tetrachloride, by the use of which a more stable solution of bromine can be obtained. About 0.1 gram of the oil (previously deprived of every trace of moisture by heat or by filtration through dry paper) is placed in a stoppered bottle of about 100 c.c. capacity, and dissolved in 50 c.c. of carbon tetrachloride, previously dried by calcium chloride. An approximately decinormal solution (8 grams per litre) of bromine in dry carbon tetrachloride, the strength of which has been accurately determined, is then added gradually to the solution of oil until a colour is obtained lasting for fifteen minutes. This is then compared with a colour similarly produced in a blank experiment, and thus the amount of bromine actually absorbed by the oil is ascertained. More accurate results are obtained by using a considerable excess of bromine, and, after the addition of a small quantity of a solution of potassium iodide and starch, titrating each with a standard solution of sodium thiosulphate.

Baron Hübl proposed the use of iodine in preference to bromine, as possessing several advantages. The action of iodine alone is not sufficiently energetic, but this was remedied by employing an alcoholic solution of iodine in conjunction with mercuric chloride. This reagent is prepared by dissolving 25 grams of iodine in 500 c.c. of nearly absolute alcohol, free

from fusel oil, and 30 grams of mercuric chloride, in an equal measure of the same solvent. The two solutions are then mixed, and allowed to stand for twelve hours. The solution requires to be standardised immediately before using it, which is done by titrating with a decinormal solution of sodium thiosulphate. With the unsaturated fatty acids or their glycerides, this sodio-mercurial chloride solution forms chlor-iodo additive products, the quantity assimilated being given in terms of iodine. For determining the amount of iodine absorption, the quantity of a drying oil recommended to be taken is from 0.2 to 0.3 gram, from 0.3 to 0.4 gram of a non-drying oil, and from 0.8 to 1 gram of a solid fat. The oil or fat is dissolved in 10 c.c. of chloroform, and the solution mixed in a stoppered flask with 20 c.c. of the standard solution of iodo-mercuric chloride and agitated; more chloroform should be added if the solution is not clear. The quantity of iodine solution added should be such that the liquid still retains a brown colour after standing from three to six hours. In order to ensure the full amount of absorption, the iodine added should be largely in excess of the quantity likely to be absorbed, even as much as double this amount may be employed. After a lapse of three to six hours, from 10 to 15 c.c. of a 10 per cent. solution of potassium iodide is run in, and after dilution with 150 c.c. of water, the free iodine, which is partly in the aqueous and partly in the chloroform solution, is titrated with a solution of sodium thiosulphate. It is necessary to make a blank experiment at the same time, in order to obtain the standard value of the iodine solution. The amount of iodine absorbed is calculated into units per cent. on the fat or oil, and is termed the iodine degree. The following numbers show the relative absorptive powers of various oils.

Nature of Oil or Fat.	Iodine absorbed, per cent.				
	Mille.	Hübl.	Archbutt.	Moore.	Wilson.
Olive oil . .	85.9–96.4	81.6–84.5	82.7–83.9	83.4	78.5–84.0
Rape-seed oil . .	110.4	97 0–105.0	100.8–102.4	103.6	100.4–102.7
Linseed oil . .	120.8	156 0–160.0	—	155.2	148.5
Cotton-seed oil .	79.5	105.0–108.0	105.9	108.7	106.0–110.1
Sesame oil . .	75.2	105.0–108.0	105.9	102.7	—
Arachis oil . .	73.3	101.0–105 0	—	87.4	—
Poppy-seed oil .	89.9	135 0–137.0	—	134.0	—
Cocoa-nut oil . .	9.1	8.9	—	8.9	—
Niger-seed oil .	—	—	132.9	—	—
Lard . . .	59.3	57.6 60.0	—	61.9	57.1–60.0
Tallow . . .	—	40.0	—	—	40 0–41.9

The experiments conducted by Mills were made with bromine, but the results were calculated by Allen into iodine numbers by multiplying the figures actually obtained with bromine by $\frac{127}{80}$, so as to facilitate comparison with the direct iodine absorptions of other observers.

It will be noticed that the drying oils, and especially linseed oil, have a high iodine degree.

Colour Reactions.—The variety of the colours developed on mixing fatty oils with different chemical reagents, naturally suggested the idea that they might be found sufficiently characteristic to be of service in determining the purity of oils, and in detecting the presence in mixed oils of such as might have been employed for purposes of adulteration. With this object in view, a series of tests were devised, many years ago, by Calvert, and also by Chateau, who instituted a very elaborate series of experiments relative to the effects produced by mixing oils with caustic soda and acids of different strengths. Some of the reactions noted, which had reference to

the various shades of colour produced, are no doubt of service in detecting adulterations, provided the amount of such adulteration is considerable, although it would be unreasonable to expect that reactions, which are liable to alterations from so many causes, should be capable of affording any trustworthy information as to the amount of the adulterant employed, more especially when in many cases the analyst is expected to draw his conclusions from data that depend on such nice distinctions of tint as come under the description of a dirty yellowish-white and a slight yellow, as well as such fine-drawn differences as are included in the numerous shades of green and brown. Moreover, it must be remembered that the shades of colour produced are liable to be greatly modified by the age and condition of the oil under examination, the proportion of fatty acids it contains, and the degree of refining to which it has been subjected.

In comparing results obtained with colour tests, it is essential that the method of working should be in every particular precisely the same, and since the tints produced are liable to be altered by very slight causes, it is advisable for reference to have samples of oils of known purity examined at the same time as those under trial.

The various colours produced by the action of sulphuric and nitric acids of different strengths on oils are many of them very characteristic, such as the violets and dark reds given by some fish oils. One of the most useful of these colour tests (especially for olive oil), as well as the easiest of application, consists in placing 20 or 30 drops of oil upon a white porcelain plate, and (when free from motion) putting in the centre of the oil one or perhaps two drops of concentrated sulphuric acid, taking note of the changes of colour that take place within five or ten minutes.

Olive, rape, cotton-seed, and mustard-seed oils exhibit characteristic changes of colour, all of them widely different from those of animal and hydrocarbon oils. With respect to the tests in which concentrated sulphuric acid is agitated with the oils, the danger of charring may be guarded against by dissolving a drop of the oil in 20 drops of carbon disulphide and agitating with a drop of the acid.

The methods adopted in applying these several tests are extremely varied.

Zecchini, in using nitric acid, recommends an acid of 1.4 sp. gr. free from nitrous acid. Equal measures of the oil and acid are shaken together for half a minute, and then allowed to stand for five or six minutes.

Hauchcorne's test, as extended by Stoddart, consists in agitating in a test tube 3–5 measures of oil with one of nitric acid, sp. gr. 1.32; the mixture is heated for five minutes by placing the test tube in boiling water. It is then taken out, allowed to stand, and the changes of colour which take place within an hour and a half noted.

Massie agitates 3 measures of the oil with 1 measure of colourless nitric acid (sp. gr. 1.4) for two minutes. The colour to be noted after the oil and acid have separated.

Glässner pours the oil cautiously into an equal measure of red fuming nitric acid, observing the colour of the oil, and also that of the zone that forms between the oil and acid on standing,

Renard has observed that anhydrous stannic chloride produces a violet colour with rosin oil.

Allen employs stannic bromide in preference to the chloride, the delicacy of the test being increased by the presence of free bromine. He prepares stannic bromide by allowing bromine to fall drop by drop on granulated tin, contained in a dry flask immersed in cold water. The stannic bromide, with excess of bromine, is then diluted with 3–4 times its volume of carbon bisulphide, in which it dissolves.

A few drops of the sample of oil are placed in a dry test tube and dis-

solved in 1 c.c. of carbon bisulphide. The bromide reagent is then gradually added, when (if rosin oil be present) a violet colour will be produced; the colour in the case of pure rosin oil is so intense as to require dilution with carbon bisulphide, in order to render the tint perceptible.

Both Beche's test and that of Baudouin are more particularly useful in the examination of olive oil, and are described as special tests for that oil.

Behaviour with Solvents.—The fixed oils are insoluble in water, and for the most part are but little acted on by cold alcohol, but they dissolve readily in boiling alcohol, especially if it be anhydrous. The glycerides of the lower fatty acids, such as those contained in cocoa-nut oil and porpoise oil, as well as the glycerides of linoleic acid and recinoleic acid are those which are the most easily soluble in alcohol, castor oil being especially distinguished by its solubility in that menstruum. The best solvents for oils are ether, chloroform, carbon bisulphide, benzene, glacial acetic acid, oil of turpentine, and light petroleum. As regards the last solvent, castor oil is an exception, being practically insoluble in all petroleum products. The solvent action of glacial acetic acid on oils has been investigated by E. Valenta. The oil is mixed with glacial acetic acid (sp. gr. 1.056) in equal proportions in a test tube, and the mixture heated until a clear solution is obtained, or the mixture begins to boil; a thermometer is then inserted and the test tube removed from the source of heat and allowed to cool slowly, the temperature being recorded at which the solution becomes turbid. This reaction has been studied by many chemists who have generally worked on quantities varying from 3 c.c. to 5 c.c., and the turbidity temperature is usually regarded as a valuable test in the examination of oils. The results obtained, however, are not quite so constant as is desirable. The turbidity temperature appears to be influenced by various causes, such as the amount of free fatty acid contained in the oil. The presence of moisture increases the temperature at which the oil becomes turbid, and appears to interfere with the solution of rape oil. The subject, however, appears to require further investigation before this test can be completely relied upon for distinguishing between the various oils ordinarily employed for illuminating purposes, as even in duplicate experiments with the same sample of oil considerable variations in the results obtained not unfrequently occur. This solvent may, however, be of service in special cases, such as that mentioned by Valenta, who proposed to employ glacial acetic acid at 50° C. (122° F.) for the separation of mineral from rosin oil, the former being but sparingly, and the latter readily, soluble in the acid.

Cohesion Figures of Oils.—In some special cases it is useful to note the figures produced when a drop of oil is allowed to fall gently on the surface of still water contained in a flat porcelain dish of sufficient dimensions. The oil first slowly spreads over the surface of the water, forming a disc which subsequently contracts, owing to the cohesion between the particles of oil; different oils producing characteristic figures in about 30 or 60 seconds. The changes that take place are of such a delicate nature, that the observer requires an experienced eye in order to be able to derive from them any information that is likely to be of service in enabling him to distinguish the several constituents of a mixed oil.

Absorption Spectra of Oils.—In some cases much useful information may be gained by observing the absorption spectra of oils, inasmuch as animal oils do not give any definite absorption bands, whilst in the case of many vegetable oils (due to the chlorophyll they contain) these bands are frequently well marked; this test is therefore of service in detecting the presence of olive, rape, or linseed oil, when mixed with sperm or lard oil. If the vegetable oils are highly refined, or have been long exposed to sunlight, their power of producing absorption bands is seriously diminished.

Exposure to Air.—The relative tendency of an oil to solidify, by absorption of oxygen from the air, may be determined by exposing thin films of the oil on glass, sized paper, or porcelain, in the same manner as has long been adopted by varnish makers in testing linseed oil, the quality of which is of the greatest importance in the manufacture of varnishes. This tendency to harden may be promoted by raising the temperature of the air. After exposure for from twelve to twenty-four hours, olive oil will remain fluid, rape oil will have become a little thicker, cotton-seed oil will have altered to a still greater extent, whilst linseed oil (which is the type of a good drying oil) will have formed a more or less solid coating. As regards other tests that have been proposed, the two following claim attention :—

The rotatory power exhibited by certain oils when a ray of polarised light is passed through them may be taken advantage of, for the detection of the presence of oils that are capable of exerting this influence, such as rosin oil, for example.

The action of sulphur chloride on oils has recently been investigated by several chemists, with the view of employing the chloride, S_2Cl_2, in testing oils, and the results of a series of experiments have been published,* but the reactions require to be more thoroughly examined before they can be relied upon, as affording trustworthy evidence of the constitution of a mixed oil.

VEGETABLE FATS AND OILS.

The vegetable fats are most abundant in the seeds and fruits of plants, and of these the most important amongst those used for illuminating purposes is the oil derived from rape-seed.

Rape-seed Oil, or Colza Oil.—This oil is obtained from several species of the genus Brassica, belonging to the natural order Cruciferæ, the seeds of a great number of varieties of which, both cultivated and uncultivated, are crushed for oil. *Brassica campestris* is largely grown in France and Germany for this purpose, as well as in other parts of the world. The seed is of a ruddy brown, and known in Germany as Kohlsaat (colza). *B. campestris*, var. *rapus* (rape), yields a blue-black seed, and that of *B. campestris*, var. *rapa* (rübsen), is nearly black. These several species are distinguished from each other by slight differences in the radicle leaves, and in the form of inflorescence; they are further subdivided into summer and winter, as well as annual and biennial plants; these several varieties gradually merge into each other, the oil yielded by all of them being practically the same. The culture is carried on in Russia, and extends eastwards from the valley of the Danube, through Persia, to various districts in India, where large quantities of some of the finest seed are grown, as well as much of inferior quality. The finest Indian seed is bright yellow, and yields as large a percentage of oil as any European seed. The Black Sea seed is well known as being of inferior quality, as is also that called "Ravison," which is the produce of an uncultivated plant of Continental growth, large quantities of which are imported into this country. More attention is paid by the crushers to the district in which the seed is grown, than to the precise species of the plant from which it is obtained. The seed from different places varies considerably in colour, as well as in its general appearance, so that from these characteristics any one in the trade can judge pretty accurately of its quality, and form a tolerably correct estimate of the amount of oil it will yield. The English, French, and Belgian seed yields from 165 to 170 lbs. per quarter of 424 lbs., or from 38 to 40 per cent., of a greenish coloured oil. The cake left after pressing out the oil has also a greenish tinge, and is of a much less pungent and irritating character than the cake from a low class of seed; so much so,

* "Jour. Soc. Chem. Ind." v. 552 [1886].

that it constitutes a valuable food for cattle, whilst cake made from inferior seed is generally used for manure. Of the Indian seed there are several well-known varieties, the finest being the yellow Guzerat (which is largely crushed at Dantzic as well as in this country), the yellow Cawnpore, and the yellow Soumneane, yielding from 35 to 38 per cent. of oil. The next in quality are the Madras, brown Calcutta, and brown Cawnpore. The yield of a very fair quality of Indian seed may be taken as being from 140 to 150 lbs. of oil per quarter of 416 lbs., equivalent to from 33 to 36 per cent., whilst the yield of uncultivated seed, such as "Ravison," could not be estimated at more than from 20 to 23 per cent.

The imports of seed into this country amounted, in 1882, to 548,806 qrs., Hull being one of the chief centres of the trade.

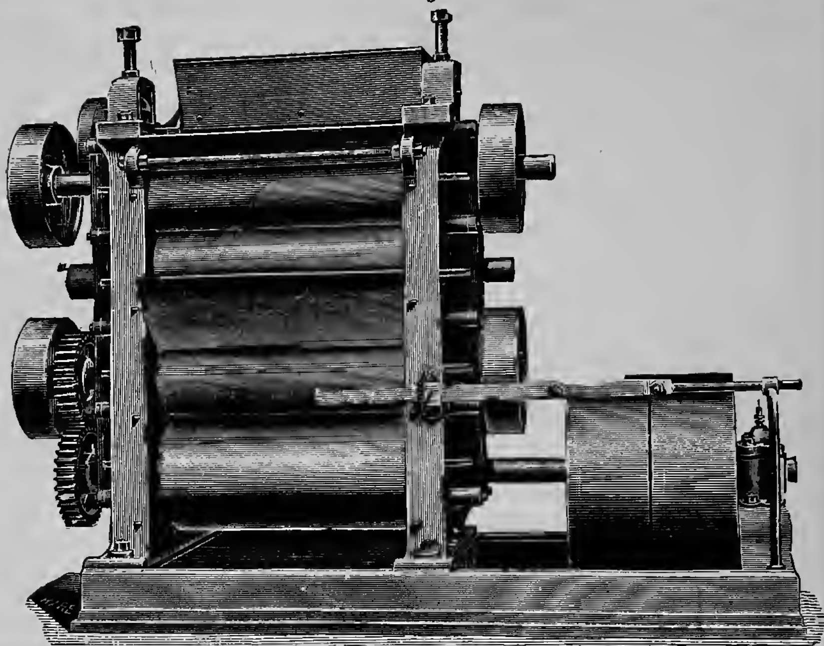
Within the last ten or twelve years great improvements have been made in the machinery employed for expressing the oil. The system of wedges and stampers, which has been in use for so many years in this country for pressing the ground seed enclosed in horsehair bags, was introduced into England towards the close of the eighteenth century by the Dutch, and is stated to be still in use in some parts of Holland, on very much the same lines as is represented in a well-known picture of David Teniers bearing the date of 1633. About the year 1845 attempts were made to apply Bramah's screw press to this purpose; but the results were not satisfactory, since it was found that a steady increase of pressure was not so effective in extracting the oil as when the pressure was applied in successive impulses. By the Anglo-American system, introduced a few years ago, the large heavy edge stones for grinding the seed were superseded by metal rolls, and the stampers and wedges by hydraulic presses, whereby a very considerable saving was effected as regards the amount of power necessary for driving the machinery as well as in the labour required, the meal being prepared for the press by moulding it into cakes mechanically, instead of by hand, as had formerly been the custom. If the cakes are moulded by hand instead of by the moulding machine they are enclosed in a "horsehair case," or a wood or paper "envelope" (Figs. 9 and 10, p. 26).

The extraction of the oil is also more completely accomplished, the oil left in the cake being now not more than about 6 per cent. instead of 8 or 9 per cent., as was usual under the old system.

The seed, cleansed from foreign matters by screening, passes at once to a series of chilled cast-iron rolls, generally five in number, set one above the other in a frame having their axes in a vertical plane, and a width of 3 ft. 6 in.* (Fig. 3, p. 24). The rolls run in bearings, free to slide in the vertical frames, the effect produced by the upper rolls being increased by a spring pressure screw. The rolls are fed from a hopper by means of a grooved roller, and the seed is crushed by the comparatively light pressure which it receives in passing between the first and second rolls. The crushed seed is then directed by means of an iron plate between the second and third rolls, where it undergoes increased pressure arising from the weight of the two upper rolls. This pressure is continually increased as it passes between each succeeding pair, so that finally the meal is as perfectly ground as it was formerly by the old system of edge stones. From the rolls the meal passes through a disintegrator that breaks up the ground mass, into a jacketed vessel heated by steam, and provided with revolving arms for the purpose of keeping the contents in constant motion, termed a kettle, Fig. 4. This vessel, which has a depth of 20 in. and an internal diameter of 3 ft. 6 in. is made of cast-iron, surrounded by a wooden frame covered with felt, and enclosed in iron sheeting. In this kettle the meal, which is kept constantly

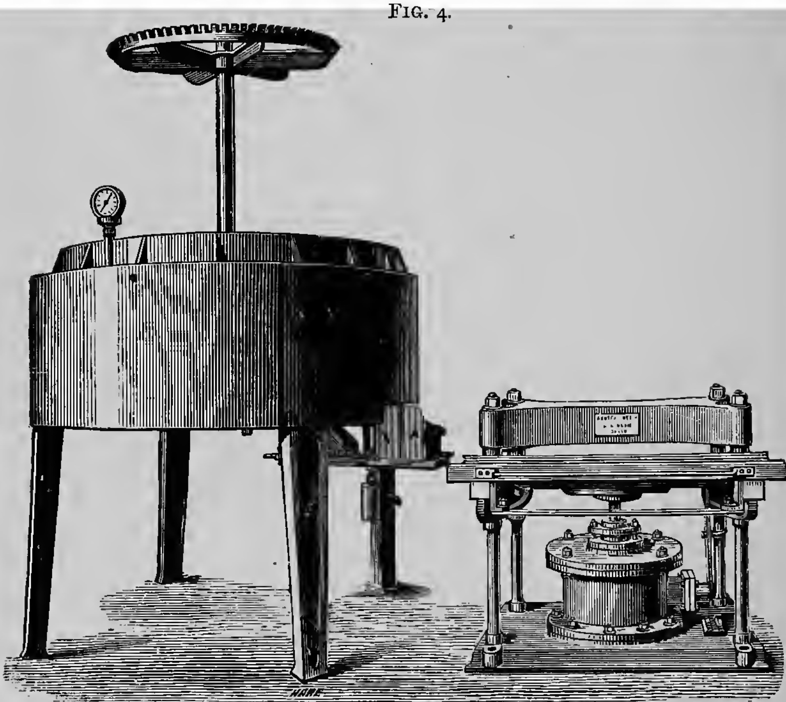
* The machinery described is that manufactured by Messrs. Rose, Dowus & Thompson, of Hull, who have kindly supplied the cuts.

FIG. 3.



Anglo-American Rolls.

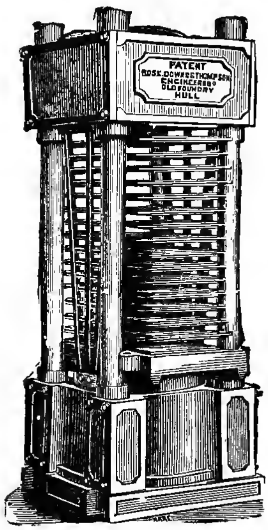
FIG. 4.



Steam Kettle and Moulding Machine.

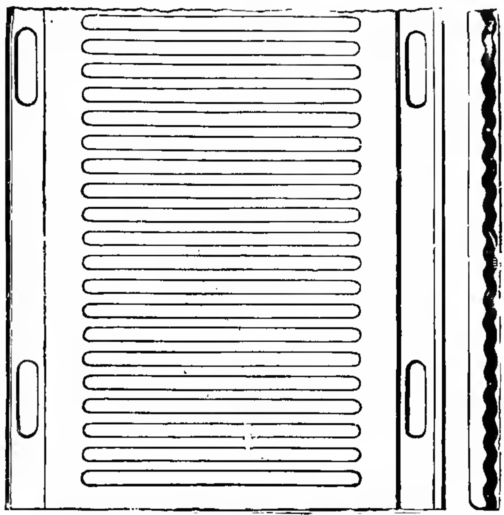
stirred, is heated to a temperature of 70°–80° C. (160°–180° F.), to facilitate the extraction of the oil. It is also supplied by means of a pipe with a small quantity of steam direct for the purpose of moistening the meal, so as to bring it into a suitable condition for pressing into cakes. The meal is withdrawn from the bottom of the kettle in a measuring box capable of holding sufficient for one cake, and placed in the moulding machine (Fig. 4), which consists of two parts, a moulding and pressing arrangement. In this machine the moist hot meal is wrapped in bagging, moulded into shape, and subjected to gentle pressure, so as to reduce the thickness of the cake to $1\frac{1}{4}$ inches, but not sufficient to extract any oil. The cakes thus

FIG. 5.



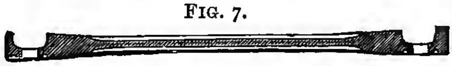
Hydraulic Oil Press.

FIG. 6.



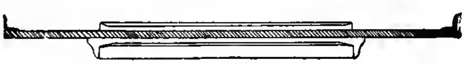
Plan and longitudinal section of Press plate.

FIG. 7.



Cross section of solid cast malleable or wrought-iron Press plate.

FIG. 8.



Cross section of compound wrought and cast malleable Press plate.

formed are then placed for the purpose of extracting the oil between the corrugated malleable iron plates, Figs. 6, 7 and 8, of the hydraulic press, Fig. 5, where they are subjected for about twenty minutes—first to a limited pressure of 2 lbs. per square inch of ram, increasing until it reaches $1\frac{3}{4}$–2 tons per square inch. Each press will hold about sixteen cakes, which is more than double the quantity that would be the case if the cakes were, as formerly, hand-made, without being compressed in the moulding machine.

When the pressure is withdrawn the cakes are taken out, stripped of their woollen coverings and placed in a paring machine, Fig. 11 (p. 26), by which they are cut to shape and their loose edges trimmed off; these parings, which

contain a considerable amount of oil, are subsequently ground under a small pair of belt-driven edge stones provided with two carte plates, the higher one being perforated so as to allow the ground material to pass through as soon

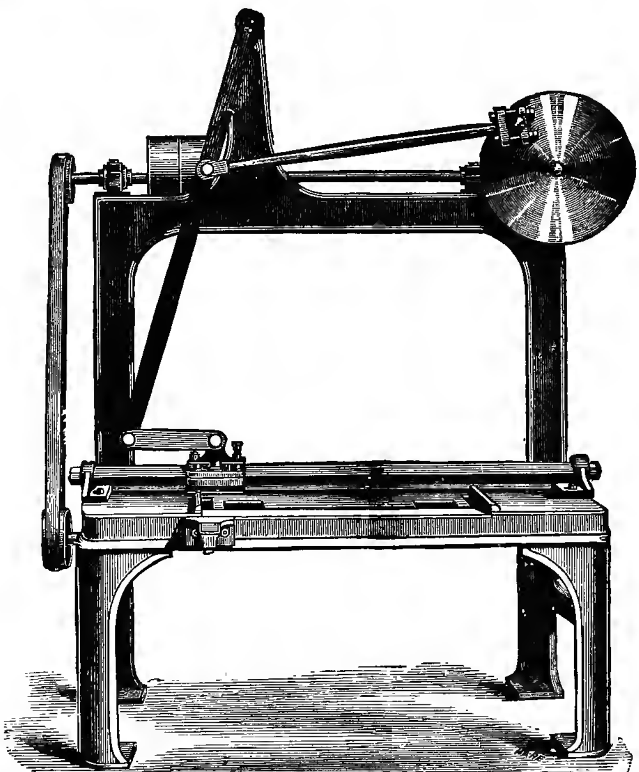
FIG. 9.

Oil press Envelope.

FIG. 10.

Oil press Hair.

FIG. 11.



Cake paring Machine.

as it is sufficiently pulverised. The meal is returned to the kettle and again subjected to pressure to extract the remainder of the oil.

The newly pressed oil is of a dark sherry colour, and contains a quantity

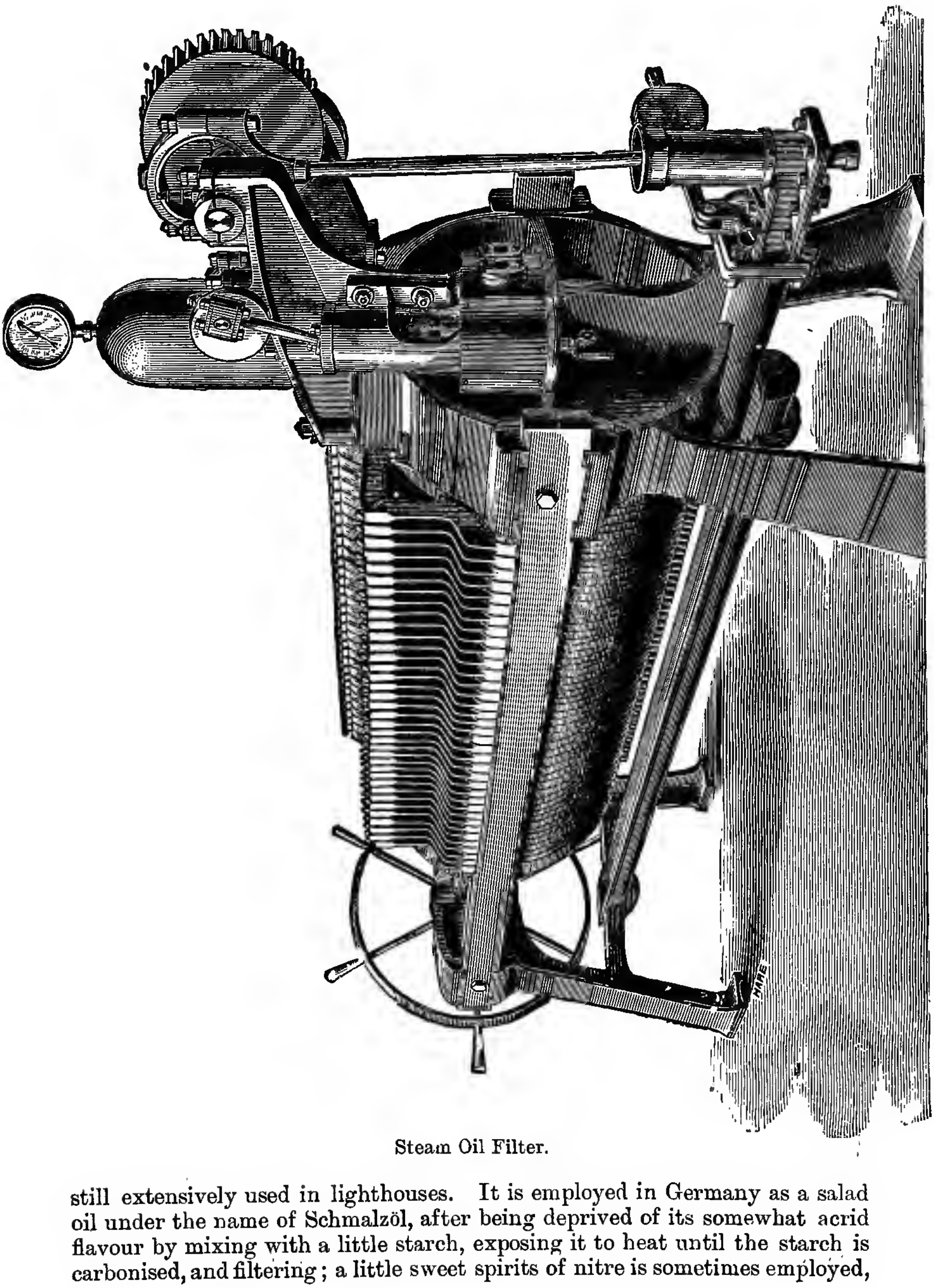
of mucilaginous and albumenoid impurities which are partially removed by gravitation, but from which it is necessary to purify the oil more perfectly by subjecting it to some process of refining, that of submitting it to the action of sulphuric acid as recommended by Thénard being generally adopted. For this purpose the oil is transferred to tanks and heated by steam pipes to a temperature of about 70° C. (160° F.); it is then vigorously agitated for about an hour with from ½ to 1½ per cent. of strong sulphuric acid, which attacks the foreign matters by removing the water they contain and charring them to a black mass. The agitation is sometimes accomplished by blowing steam through the mixture, which is then allowed to remain at rest for five to six hours for the charred impurities to collect together. If any considerable amount of sulphuric acid were employed, the oil itself would be acted on; this must, of course, be avoided as far as possible. The oil is then conveyed to a washing vat, where it is mixed with hot water containing a little caustic soda, with which it is briskly stirred for an hour in order to remove the last traces of acid; a small quantity of soap is formed which rises as a scum to the surface, bringing some of the impurities with it. The mixed water and oil remains for a week in a clearing tank to allow the water to separate, which is sometimes facilitated by the addition of a little salt. The oil if clear is then drawn off, or if necessary it is filtered through bags or some dry porous material such as charcoal or sawdust; fuller's-earth is frequently used for the filtration of oil. It has been proposed by Mayer to transfer the oil direct from the presses to a centrifugal machine by which the oil is clarified, the albumenoid and mucilaginous impurities being deposited on the periphery of the drum, leaving the oil clear. The oil is sometimes passed through a hydraulic steam filter (Fig. 12, p. 28), by which a great saving of time is effected as well as storage space, as by its use the clarified oil can be conveyed to the stock cisterns as rapidly as it is produced by the presses.

As far back as the year 1843 it was proposed by Fisher of Birmingham to extract oil from seeds by using carbon bisulphide as a solvent, and twelve years later a patent was taken out by Deiss of Brunswick in connection with the same subject; but partly owing to the disagreeable odour imparted to the oil as well as to the exhausted seed this method never came into general use. The seed when prepared for extracting the oil by any solvent process, is not ground into fine meal, but is simply crushed and placed in a series of tightly closed cylinders. The solvent is admitted to the first of the series for fifteen minutes, and then passed on to the next and so on, the cylinder containing the most exhausted seed being always the one to be charged with the fresh solvent. The solution when saturated with oil is conveyed to a distilling apparatus in which the solvent is driven off by heat and recovered for further use. The last traces are removed from the oil as well as from the exhausted seed by driving steam through them. In 1863 an English patent was taken out for the use of volatile hydrocarbons obtained from petroleum and shale oils, as solvents for the fixed oils, and the development of the American petroleum industry since that period has brought this system of extraction into practical use. Petroleum spirit has the advantage of dissolving the oil without taking up much resinous or colouring matter, and is therefore well adapted for the extraction of oils required for edible purposes, or for pharmaceutical preparations. Up to the present time, however, the extraction of oil from seeds by means of solvents has only been conducted on a comparatively small scale.

When the extraction is carried out by means of pressure, heating the meal renders the oil more fluid, and it is consequently more easily squeezed out; but when a very fine oil is required, a better coloured and purer oil can be obtained by pressing the meal without the assistance of heat.

Refined rape oil is largely used for lubricating purposes, but its chief value consists in the excellent properties it possesses as an illuminant. It is considered by the Trinity House to be one of the finest oils for lamps, and is

FIG. 12.



Steam Oil Filter.

still extensively used in lighthouses. It is employed in Germany as a salad oil under the name of Schmalzöl, after being deprived of its somewhat acrid flavour by mixing with a little starch, exposing it to heat until the starch is carbonised, and filtering; a little sweet spirits of nitre is sometimes employed,

in order to remove any disagreeable flavour. In India it is used in the preparation of curries and other hot dishes, as well as for other edible purposes.

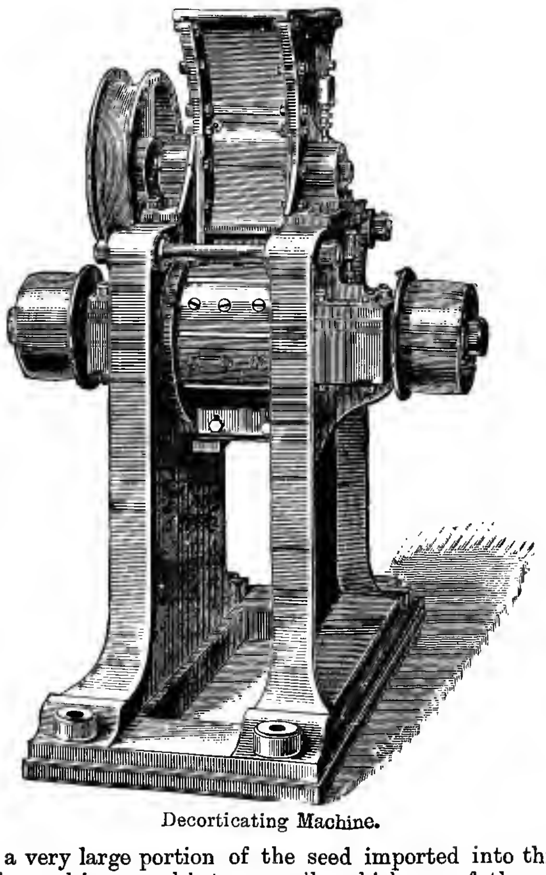
A genuine refined rape oil should have a sp. gr. of 0.915; if the sp. gr. of a sample be as low as 0.914 or higher than 0.916, it should be regarded with some suspicion; most of the usual adulterants have a higher specific gravity than the genuine oil. As regards its chemical composition, it differs from most other fixed oils in consisting to a great extent of a glyceride of brassic acid, $C_{22}H_{42}O_2$.

The oil may be impure from the inferior quality of the seed crushed, which may have contained foreign seeds, or it may be adulterated with a variety of lower priced oils. The most usual adulterants are mineral oil, rosin oil, and linseed oil. Mineral and rosin oils may generally be detected, as already mentioned, by the taste, or the presence of these oils may be indicated by the fluorescence they exhibit, unless "debloomed" mineral oil has been employed, in which case the quantity of unsaponifiable oil should be approximately determined and its character investigated. Rosin oil has a remarkably high density, varying from 0.980 to 1.1, and it consequently tends to raise the sp. gr. of rape oil when mixed with it. Its presence may also be detected, as already mentioned, by the colour test with stannic bromide, and also by its effect on polarised light, which is generally dextro-rotatory. The presence of either hempseed, cotton-seed, or linseed oil would be likely to produce an abnormal rise of temperature on subjecting the sample under examination to the Maumené test. The colour observed on adding a drop of concentrated sulphuric acid to 20 drops of oil would be of great assistance in detecting in rape oil the presence of several oils not unfrequently employed as adulterants, and in the case of rosin or animal oils the reaction would be very marked. Animal oils may generally be detected by taste and smell on warming the sample. The presence of linseed oil would be indicated by increased drying properties; cotton-seed oil by a rise in the temperature at which the oil solidifies, in the higher melting point of the fatty acids, and by the increased density. In testing the drying properties of a sample of oil, Archbutt recommends placing about a gram of the oil in a watch-glass side by side with a similar quantity of a sample of oil known to be genuine, exposing the samples in a water oven for about sixteen hours, and observing the relative tendency to solidify subsequently exhibited by the two samples.

Cotton-seed Oil.—This oil is expressed from the seed as imported, or from the decorticated seed of the cotton plant, *Gossypium barbadense*, as well as other varieries, and is comparatively of recent manufacture. Attempts were made in America to obtain the oil contained in cotton-seed about the year 1834, and were subsequently several times repeated. Although these attempts were successful as regards the production of oil, they had eventually to be relinquished as unprofitable. In the year 1852 cotton-seed was imported into this country from Egypt, for the purpose of having the oil extracted, which led to more encouraging results, and within the last ten or twelve years the oil has become an important branch of industry. In 1881 the annual production reached 8,000,000 gallons, and the present supply is estimated at more than three times this quantity. In the year 1887 500,000 tons of seed were crushed in the United States, and it is estimated that 300,000 tons of Egyptian seed are annually crushed in Great Britain. In the first half of 1889 the imports into Hull, chiefly from Alexandria, amounted to 77,119 tons. The yield of oil is somewhat variable, depending upon climate and the locality in which the seed is grown; but the average quantity may be taken to be from 20 to 25 per cent. on the decorticated seed, the Egyptian seed yielding rather more than the American. The seed, after undergoing the process of ginning to separate the cotton fibre,

still retains a small quantity of short fibre termed "linters," which causes the seed to cling together into masses, that are cut in pieces by a machine constructed for this purpose, so as to prepare it for being screened from the sand and other foreign matters with which it is associated. The short fibres are detached and used for paper-making, and the seed is either crushed without removing the husks, or it is passed through a decorticator (Fig. 13), a machine which cuts off the husk by means of knives rotating at a high velocity, and separates the kernels from their outer covering. In America it is usually decorticated, but although this is done to some extent in this country, it is by no means general. Very little, if any, decorticated cake is now made in

FIG. 13.



Decorticating Machine.

Hull, where a very large portion of the seed imported into this country is crushed. The seed is ground between rolls, which are of the same general character as those already described, but for cotton-seed the rolls are fluted and run at differential speeds. The meal is heated in a steam-jacketed vessel to a temperature of from 95°–102° C. (204°–215° F.), and the hot mass is filled into stout woollen bags, and subjected to hydraulic pressure to extract the oil. By pressing at ordinary temperatures without heating the meal a portion of the oil of an exceptionally fine character is obtained.

The oil is agitated with boiling water or steam to coagulate as far as possible the albumenoid and other impurities, which for the most part separate by gravitation on standing. The oil is then either at the ordinary

temperature, or gently heated to 26°–29° C. (80°–85° F.), put into a tank, and briskly agitated with 10–15 per cent. of a solution of caustic soda having a sp. gr. of 1.07. The caustic soda attacks the albumenoid and resinous impurities as well as the colouring matters, which are subsequently deposited on standing together with a small quantity of saponified oil, forming a very dark-coloured sediment, known in the trade as "mucilage." The supernatant oil, which is of a light brown or straw colour, is drawn off when clear and washed with water. The loss of oil sustained in this process of refining varies considerably, according to the quantity of the oil, but about 5 per cent. may be regarded as the average, although this may be considerably exceeded in many cases. In order to avoid loss from saponification, the use of carbonate of soda instead of caustic has been proposed, and has been to some extent employed, but, as might be expected, it does not act as effectually in removing impurities. When a colourless oil is required, a bleaching agent such as an alkaline hypochlorite is sometimes resorted to; but this is not absolutely necessary, as the oil may be decolorised by agitating it at a temperature of 150°–175° C. (300°–350° F.), with fuller's-earth and subsequent filtration.

When exposed to a temperature of 0°–4° C. (32°–40° F.), cotton-seed oil partially solidifies, and when subjected to pressure the fluid portions can be squeezed out, leaving behind those which are of a more solid consistency, the latter constituting what is known in commerce as cotton-seed stearin, which is said to be employed in the adulteration of lard and tallow and in the preparation of butter substitutes.

The residuum or "mucilage" left on refining is boiled with open steam, and treated with sulphuric acid, which combines with the alkali it contains, liberating the fatty acids, and forming a thick black grease. This black mass is subjected to the action of superheated steam, which distils over the fatty acids, leaving behind a hard black pitch. The distilled palmitic, stearic, and oleic acids are separated by pressure, and the solid fatty acids thus obtained (which can be rendered nearly colourless by repeating the distillation) form no inconsiderable portion of the cotton-seed stearin of commerce.

The colouring matters of cotton-seed oil possess powerful dyeing properties, and the black alkaline mucilage which contains these colouring matters in a more or less altered form, when rubbed on the hands discolours them so effectually that the stain cannot be removed without considerable difficulty.

Olive Oil.—This oil is obtained from the fruit of the olive-tree (*Olea europæa*), of which there are numerous varieties known to the modern cultivator, although only comparatively few are grown to any large extent. The olive thrives best in a calcareous soil, and near the sea-coast; it bears a stone fruit, the fleshy integument of which contains the sweetest of all vegetable oils. It is of slow growth, begins to bear fruit when five years old, and attains great age, lasting for several centuries; when not kept back by pruning it grows to a large size, producing a hard and tough timber. It is a native of Asia, and has long been cultivated in Southern Europe, more particularly in Greece, Italy and Spain, the broad-leaved olive of Spain bearing a larger fruit than that grown in Italy. From Europe the olive was introduced into America, where it flourishes, more especially in Chili and Upper California; it has also found a climate admirably suited to its growth in Queensland and South Australia.

Under careful cultivation the trees are planted in rows, and manured with woollen rags or other nitrogenous fertilisers, much attention being paid to the pruning. In the South of Europe the trees come into bloom in April, and the fruit is of full size in November, when the harvest (which lasts for

seven or eight weeks) commences. The crop is of a somewhat uncertain character, and on an average a good season is not to be expected more than once in three years. The trees are liable to be affected with fungoid growths, the shoots are sometimes attacked by a species of coccus, the leaves eaten by caterpillars, and the fruit injured by the olive-fly. The trees also suffer in the event of a long-continued drought, the fruit falling off before it has reached maturity; to guard against which, artificial irrigation is resorted to in some districts. To obtain the finest oil, the fruit should be gathered by hand before it gets too ripe, for if allowed to remain until it falls, or the trees are beaten with poles (as is the case with the bulk of the fruit), the quality of the oil obtained is inferior.

The olives are spread over a floor, where they remain for three or four days to dry, the drying being occasionally assisted by a slightly elevated temperature. For extracting the oil, the olives are crushed, placed in coarse bags or rush mats, and subjected to pressure, which, if oil of the best quality is desired, should be done as soon as possible after the fruit has been gathered. In order to obtain the very finest or "virgin" oil, the pulp of hand-picked fruit is subjected to a very moderate pressure; the residue is broken up in the bags, treated with hot water, and again subjected to pressure, to extract the remainder of the oil. For ordinary oil, the pulp is more heavily pressed, the yield being sometimes increased by allowing the mass of fruit in the storehouses to ferment slightly (the temperature never being allowed to exceed 36° C.; 96° F.), which softens the fruit and facilitates the extraction of the oil. In some districts, the machinery employed for crushing and pressing the fruit is still of a very crude description, but iron rolls are gradually taking the place of those of a very primitive age which were made of stone, and hydraulic presses are superseding those of a more simple construction that have been employed for many centuries. The crushed cake is sometimes broken up, stirred with warm water, and pressed for a third time, yielding an inferior description of oil. The residue after pressing, or "marc" (as it is termed), still retains from 5 to 10 per cent. of oil, which is extracted by the use of some solvent such as carbon bisulphide or light petroleum. It has recently been proposed (instead of using a solvent) to extract the last portions of oil by subjecting the "marc" to the action of superheated steam by which any oil it may contain is carried over as a distillate at a temperature of 150°–200° C. (302°–392° F.), a small quantity of the oil being liable to be decomposed towards the close of the operation. The oil is allowed to remain in large tanks for two or three months to afford time for the mucilage to deposit, and sometimes it is subjected to a further process of purification by agitating it with a solution of caustic soda, the clear oil obtained after separation of the water and impurities by subsidence being drawn off. The character of the refined oil varies considerably according to the quality of the fruit, the care taken in its treatment, and the methods employed in the extraction. Some descriptions are pale yellow, whilst others have a dark green tinge. The green colour that is natural to some vegetable oils is due to chlorophyll, which becomes changed by exposure to sunlight, or to any bleaching process. The green colour is sometimes artificially given to olive oil in order to meet the requirements of those who have a preference for oils possessing this tint.

The finest olive oil was at one time that imported in the well-known Florence flasks, but no dependence can now be placed on the quality of such oil, as it is very frequently adulterated. It is stated that these flasks are often filled in London with cotton-seed oil, which is sold as fine salad oil. The oils that are held in the highest estimation are those which are employed for edible and culinary purposes, the best of which is known as "Finest Cream Sublime," imported from Leghorn. The Provence, Florence, and Lucca

oils also belong to this class. The oils from Spain, Greece, Tuscany, Gallipoli, Genoa, Sicily, Tunis, and Mogador are chiefly used for burning in lamps and for lubricating machinery, the lowest qualities being converted into soaps. That known as Marseilles or Castile soap is made from olive oil. For burning and lubricating purposes, freedom from acidity is a great desideratum, and in this respect the Spanish oil from Seville is one of the best of those mentioned as used for these purposes. There are peculiar facilities at Gallipoli (which is situated on a steep insulated rock on the eastern shore of the gulf of Taranto) for keeping the oil fresh and sweet, in the remarkable tanks that are cut out of the solid limestone rock, to which the oil is brought from a considerable distance for storage. Large quantities of olive oil are refined at Bordeaux, although not situated in the oil-producing districts.

The usual density of olive oil at 15.5° C. (60° F.) is 0.916–0.917, the presence of any considerable quantity of free fatty acids (a not unfrequent occurrence) having a tendency to lower the density. The sp. gr. of a very acid oil may even be as low as 0.914.

Olive oil has a higher market value than most of the other vegetable oils, and it is consequently liable to be largely adulterated with lower priced oils, and to such an extent is this admixture with foreign oils carried, that not unfrequently a so-called olive oil is found to contain not more than from 50 to 60 per cent. of genuine olive oil. The oils most frequently employed in this adulteration are cotton-seed oil, sesame (gingelly) oil, arachis (earth-nut), rape-seed, and poppy-seed oil. Large shipments of cotton-seed oil are made from the United States to Marseilles, a great portion of which finds its way back again under the name of olive oil, after paying a considerable duty. The low-priced olive oils of Italy, Tunis, Sicily, and Algeria are often mixed with cotton-seed oil and exported as fine olive oil. Linseed oil, walnut oil, and lard oil are also occasionally employed as adulterants. Indications of the nature of the sophistication may be ascertained by subjecting a sample of olive oil to the following tests.

The Maumené Test.—The rise of temperature on mixing with sulphuric acid will be considerably increased by the presence of cotton-seed oil, and also by that of most of the other oils generally employed in the adulteration of olive oil.

Elaïdin Test.—It has already been stated that genuine olive oil usually gives a lemon-coloured elaïdin of a very solid character. In adulterated samples the solidification is frequently retarded, and the elaïdin formed is of a softer description, whilst in some cases it may assume an orange or a red colour. Archbutt has made a great number of experiments with this test, and the results of his extended experience have led him to conclude:—

(1) That the test should be carried out at a temperature of 25° C. (77° F.), and that this temperature should be maintained throughout the experiment.

(2) That the length of time required for solidification is of greater importance than the ultimate consistency of the elaïdin.

(3) That the reagent, if properly prepared and carefully preserved, may be employed so long as it retains its deep green colour.

(4) That even when every precaution has been taken in conducting the experiment, a genuine olive oil may sometimes fail to yield an elaïdin of the usual solidity, so that in condemning an oil as adulterated, it would not be wise to rely entirely on the results obtained by this test.

It was pointed out by Moschini many years ago that if the olive oil had been exposed to sunlight, the hardness of the elaïdin obtained from it by the use of this test was diminished. The precise mode of carrying out the test adopted by Archbutt is described in the "Journal of the Society of

Chemical Industry," v. 306 [1886]. As the result of experiments on eleven different samples of olive oil believed to be genuine, he found the time required for solidification at 25° C. (77° F.) to vary from about 200 minutes to about 400 minutes. With mixtures the following results were obtained :—

	Minutes required for solidification.
Olive oil alone	230
The same oil + 10 per cent. of rape . .	320
,, + 20 ,, ,, . .	from 9 to 11½ hrs.
,, + 10 ,, of cotton .	,, ,,
,, + 20 ,, ,, . .	over 11½ hrs.

Saponification.—The determination of the quantity of potash, KOH, required for the complete saponification of a sample of olive oil (besides that required for neutralising the free fatty acid) affords information which is of assistance in judging of the purity of the sample. A genuine oil should require about 19 per cent. of KOH. This estimate is based on results obtained by Archbutt from the examination of 300 samples, which varied from about 18.8 to 19.2 per cent.

Iodine Absorption.—This test is of assistance in determining the genuineness of a sample of olive oil. According to the observations of Hübl, a pure olive oil does not absorb more than about 85 per cent. of iodine, whilst rape-seed oil absorbs 100 per cent., sesame and cotton seed oil 105 per cent., poppy-seed, hempseed and walnut oil 142 per cent., and linseed oil 156 per cent., of iodine.

Colour Tests.—In the preliminary examination of an olive oil, placing a drop of concentrated sulphuric acid in the centre of 30 drops of oil is of great service in drawing attention to any adulteration. The colour produced by a genuine olive oil is orange yellow, or very pale brown, generally surrounded by a broad band of a light green shade. Most of the other oils produce very much darker tints, varying according to the nature and quantity of the oil used as an adulterant, a knowledge of which can only be obtained by actual experiment.

Special Tests.—Baudouin tests for sesame oil, by shaking up in a test tube from 5 to 10 c.c. of the fatty acids (obtained from the sample under inspection, and dried at a temperature of 110° C.), with hydrochloric acid containing 2 per cent. of sugar, a red coloration being produced by the fatty acids of sesame oil, which is not the case with the fatty acids of olive oil.

Brullé tests for any seed oil by placing 10 c.c. of the oil under examination in a test tube, adding 0.1 gram of dry powdered albumin and 2 c.c. of nitric acid. The test tube is then heated until the acid boils, the test tube being so inclined as to cause the ebullition to mix the oil and acid thoroughly together. If the olive oil be genuine, only a faint greenish yellow coloration is produced; but should any seed oil be present to the extent of 5 per cent. the colour will be an orange tint of a darker or lighter shade, according to the amount of adulteration. This test has met with the approval of a committee of the Agricultural Society of the Alpes-Maritimes.

The adulteration of olive oil with cotton-seed oil reached such enormous proportions, that it became a matter of the greatest importance to ascertain the best method of detecting this adulterant. In 1886 a Commission was appointed at Florence to inquire into the value of a test proposed by Bechï. After thoroughly investigating the matter, experiments having been made with olive oil obtained from several districts, as well as in different conditions, and with cotton-seed oil from various sources, the Commission issued a favourable report as to its trustworthiness, when the amount of adulteration was as much as 20 per cent. This test was based on the reducing action exerted by cotton-seed oil on silver nitrate. The test has since been greatly

improved by Milliau, who, instead of working with the oils direct, makes use of the fatty acids obtained by saponification of the oil, whereby the delicacy and trustworthiness of the test has been much increased. It is asserted that as small a quantity as 1 per cent. of cotton-seed oil may be detected, if the test be properly carried out, which should be as follows:—5 c.c. of the melted fatty acids are dissolved in 20 c.c. of absolute alcohol in a wide test tube. The solution is brought to the boil, and then 2 c.c. of a 30 per cent. solution of silver nitrate is added. The fatty acids of cotton-seed oil under these circumstances react with the silver nitrate, producing an immediate black deposit, whilst the fatty acids of olive oil do not bring about any such reduction of the silver salt. W. H. Wiley, in using this test for the detection of cotton-seed oil in lard, prefers to employ a round-bottomed porcelain dish capable of holding about 50 c.c., instead of a test tube, and to acidify the silver nitrate solution by the addition of from 0.5 to 1 per cent of nitric acid. He also considers that the fatty acids, if kept for any length of time, lose their power of reducing the silver salt.

Labiche mixes the sample of oil under examination with an equal volume of a saturated solution of neutral acetate of lead, the mixture being briskly stirred, when an orange-red coloration is produced if the sample contains 20 per cent. of cotton-seed oil. Some adulterants (such as walnut oil) may be detected by the peculiar flavour they impart to the olive oil.

Olive Kernel Oil.—This oil, which is frequently extracted by means of a solvent, has a higher density than olive oil, the sp. gr. being about 0.920

Madia Oil.—The plant from which this oil is obtained (*Madia sativa*) is indigenous to Chili, and has been successfully cultivated in Asia Minor and Algeria. Its introduction into Germany and the South of France (owing to the irregularity with which the seed ripens in those countries) has not been attended with the amount of success that was anticipated. The seeds (which are very small) yield from 30 to 40 per cent. of oil, which is of a yellow colour, having a sp. gr. of 0.926. The finest oil obtained by cold pressure can be used as a salad oil, that of inferior quality is employed for illuminating purposes.

Palm Oil.—This vegetable fat, obtained from the West Coast of Africa, is extracted from the fruit of several species of palm, but chiefly from *Elœis guineensis*, an oil palm growing in tropical Africa to a height of 70–80 feet. The spadix of this palm, containing the fruit, which is of an orange or reddish colour and about the size of a pigeon's egg, will often weigh as much as 20 lbs. The fruit is a drupe, consisting of a strong kernel surrounded by a firm fleshy integument of a vascular character, the cells of which contain the oil or fat in drops or lumps. The hard stone also yields an oil, but of a different character, more nearly resembling cocoa-nut oil, and which is known in commerce as palm-nut or palm-kernel oil.

The establishment of the trade in palm oil was of material assistance in suppressing the African slave trade; the natives finding it more profitable to sell their oil to the English, who were almost their exclusive customers, than to encounter the risks incurred in attempting to run the blockade of their ports with a cargo of slaves, so that the banks of the Senegal and Gambia rivers became in process of time lined with rude factories for the extraction of the oil.

Palm oil is obtained by pressure, or by boiling with water; in the latter case the oil, which is when cold of various shades of colour from yellow to red, floats on the surface of the water; it is skimmed off, and put into casks, in which it becomes on cooling of a semi-solid consistency. In order to facilitate the extraction of the oil, the fruit is sometimes allowed to remain in heaps until a certain amount of fermentation has taken place. The oil has a slightly sweet flavour and an odour resembling that of orris root; if

exposed to air it rapidly becomes rancid and assumes a paler colour. It consists essentially of tripalmitin and triolein, with varying quantities of palmitic and oleic acids; it always contains a very considerable proportion of free fatty acids, the amount of which increases with the age of the oil. This acidity raises the melting point of the oil, and causes it to exert a powerfully corrosive action on metals. Pelouze and Boudet found fresh palm oil to consist of free fatty acids to the extent of one-third of its weight. In a sample melting at 31° C. (88° F.) the fatty acids amounted to one-half its weight, and in a sample melting at 36° C. (97° F.) the fatty acids were as much as 80 per cent. The results of the more recent investigations by Tate and Archbutt have shown that commercial samples of palm oil are liable to contain as much as 80 per cent. of free fatty acids calculated as palmitic acid, $C_{16}H_{32}O_2$.

The melting point of fresh palm oil ranges from 27°–36° C (80° to 97° F.), but that of an oil containing a large proportion of fatty acids may be as high as 42° C. (108° F.); whilst its consistency may vary from that of soft lard to hard tallow. The oil generally contains water varying in amount from 2 to 16 per cent., as well as solid impurities, 2 per cent. being allowed in the trade as representing the normal amount. The water may be expelled by exposing the oil to a temperature of 104° C. (220° F.), and the amount of solid impurities may be ascertained by dissolving the oil in light petroleum and allowing the impurities to subside; these may then be collected, washed with a little ether, dried, and weighed.

The sp. gr. of the oil is about 0.920–0.927, at a temperature of 15.5° C. (60° F.), and 0.857–0.859 at the temperature of boiling water.

The quality of palm oil, as might be expected from the vast extent of country whence it is obtained, varies considerably. The best brand, that of Lagos, is most in demand, and commands the highest price. In 1880 the quantity of palm oil imported into England was 51,000 tons, at a closing price for Lagos of £30 per ton. In 1883 the imports did not exceed 37,000 tons, the price for Lagos being £40 per ton. In 1885 the quantity amounted to 45,000 tons, the price for Lagos being only £26 per ton, the price being still further reduced at the close of 1886 to £22 per ton.*

Palm oil is extensively employed in the preparation of railway grease, and in the manufacture of candles. Palm oil as imported does not usually undergo any special bleaching process. Much of the colouring matter is decomposed during the saponification and subsequent processes to which it is subjected for the separation of the fatty acids, and remains behind with the black residue that is left on distilling over the fatty acids by means of superheated steam, or it is expressed with the oleic acid when the fatty acids are subjected to pressure.

When a specially colourless fatty acid is required, recourse must be had to one of the usual and well-known processes for bleaching fatty substances, such as exposure to the action of light, which may be done by simply exposing the fat in thin layers to the influence of the sun, or the liquid fat may be heated in a tank from which portions are continually raised by some simple mechanical arrangement and allowed to fall back again in thin streams; or a current of air is passed through the oil heated to a temperature of 54°–60° C. (130°–140° F.). Sulphurous acid gas is sometimes admitted by means of a perforated tube to the bottom of a closed vessel containing the oil to be bleached, the gas being drawn through the liquid by means of a Kœrting's air suction, or steam-jet suction springs, attached to the top of the vessel. Direct oxidation of the colouring matter may be effected by passing oxygen gas through the oil, the oxygen being obtained by the action

* Report on Oil and Fats to the Royal Commissioners of the Colonial Exhibition of 1886, by Leopold Field.

of sulphuric acid on binoxide of manganese, or by Brin's process, or supplied in the shape of ozone or peroxide of hydrogen; or the bleaching may be attained by the use of more powerful chemical reagents such as chlorine or chromic acid. Hypochlorous acid, or a hypochlorite, is also used in the bleaching of oils, a solution of sodium hypochlorite being employed in France under the name of Eau de Javelle, and potassium hypochlorite under the name of Eau de Labarraque.

Palm-nut Oil, or Palm-kernel Oil, is obtained from the kernels of the fruit of *Elæis guineensis.* Its composition is of a more complicated character than that of palm oil, more nearly resembling cocoa-nut oil in this respect, consisting, as it does, of the glycerides of myristic, lauric, capric, caprylic, and caproic acids, besides those of stearic, oleic, and palmitic acids. It ranges from 0.866 to 0.873 at a temperature of 99° C. (210° F.).

Oil of Illipi (Illipa, Epei).—This is a semi-solid fat, bearing some resemblance to palm oil, and is obtained from the fruit kernels of *Bassia longifolia,* which flourishes on the coast of Coromandel; the seeds yield about 30 per cent. of oil having a sp. gr. of 0.947; it rapidly becomes rancid in the hot climate of India.

Mahwa Oil, or Mahwa butter, is obtained from the fruit of *Bassia latifolia,* a tree which is extensively cultivated throughout India, bearing flowers that are used as an article of diet, and from which an intoxicating liquor is distilled, having a flavour that is considered by some to bear a slight resemblance to that of Irish whisky. It is stated that six gallons of proof spirit can be obtained from 112 lbs. of the flowers. The oil has a sp. gr. of 0.972, and is used for cooking purposes.

Phulwara Oil.—This oil is of the consistency of soft lard at a temperature of 35° C. (95° F.). It is obtained from the seeds of *Bassia butyracea,* the Indian butter tree. The seeds, which have somewhat the appearance of blanched almonds, are bruised to a pulp, and placed in bags under a weight until the oil is pressed out. The oil is much used as an adulterant for "Ghee," the peculiar description of butter made from milk, and which forms such an important article of diet with the natives of Hindostan.

Shea Butter (Galam, Nungu, Bambouk butter) is obtained from *Bassia Parkii* (*Butyrospermum Parkii*), a plant indigenous to tropical Africa. The term Shea means in the native language tree butter. This fat much resembles palm oil, for which it is sometimes mistaken; it is, however, of a firmer consistency, and more like a dirty white or yellowish tallow; its melting point varies, that of some samples being below 27° C. (80° F.), whilst that of others is as high as 43° C. (109° F.). The seeds are dried in the sun, ground in a mortar, and kneaded into a dough with warm water, the fat being extracted with hot water. It has a sp. gr. of 0.859 at the temperature of boiling water. The fat generally contains a considerable quantity of free fatty acids, and has a somewhat agreeable flavour and odour.

Cocoa-nut Oil, or, more correctly, cocoa-nut oil as imported, is a white, rancid fat of the consistency of lard, extracted from the kernels of *Cocos nucifera* (*butyracea*), the cocoa-nut palm, that flourishes in the East Indies, throughout the tropical islands of the Pacific Ocean, and in tropical America. It is extensively cultivated on the coast of Brazil, and forms a very important part of the productions of the island of Ceylon. The cocoa-palm grows to the height of 60–90 feet; the stem is soft and fibrous, and is marked with rings, occasioned by the fall of the leaves (two of which are said to drop off every year), about a dozen leaves, which are sometimes as much as 12 or 14 feet in length, forming a tuft at the top of the tree. In wet seasons, blossoms will make their appearance every five or six weeks, so that fresh flowers and ripe nuts may sometimes be found on

the tree at the same time. The juice, which exudes on making an incision into the unexpanded flower spathes, is known as toddy, which when boiled down produces a coarse brown sugar termed in India jaggery, or, if allowed to ferment, yields a spirit generally known as arrack. The tree begins to bear fruit when it attains the age of six or seven years, the shoots from which the flowers subsequently emerge making their appearance during the sixth year. On arriving at maturity, the tree will bear on an average from 60 to 120 nuts annually, the quantity depending greatly upon soil and climate. The number of nuts in a bunch varies from five to fifteen, and on a good soil a tree may produce from eight to twelve bunches every year, and will continue to bear fruit for seventy or eighty years. The kernels, when cut up and dried in the sun, are known in commerce as copperah, or more generally as "copra," containing from 60–80 per cent. of fat. The natives of the South Sea Islands simply bruise the copra and expose it to the sun in perforated pots, the oil running out into vessels placed beneath. The mills in Ceylon are conducted by Europeans, and are well supplied with machinery suitable for grinding the copra, and subjecting the ground material to hydraulic pressure; a great deal of copra, worth in London from £15 to £16 per ton, is shipped to Europe for the extraction of the oil. The copra contains two descriptions of fat differing in consistency, so that whether the oil expressed is of a fluid or more solid nature depends greatly on the temperature and pressure. The residue left after the fat has been expressed is known as "poonac." Cocoa-nut oil is of a complex constitution, for besides the glycerides of myristic ($C_{14}H_{28}O_2$), palmitic, and stearic acids, it contains the glycerides of lauric acid ($C_{12}H_{24}O_2$), capric acid ($C_{10}H_{20}O_2$), caprylic acid ($C_8H_{16}O_2$), and caproic acid ($C_6H_{12}O_2$).

Cocoa-nut oil requires a strong alkaline lye for its saponification, and the soap formed is much more soluble in salt water than other descriptions of soap, thus rendering it particularly adapted for use as a marine soap. Cocoa-nut stearin and olein are the products obtained by subjecting the oil to pressure.

Cohoon Oil (Cohune oil) is obtained from the nut of the cohune palm (*Attalea cohune*); it is a white, hard fat, solid at 22° C. (72° F.), having a sp. gr. of 0.875 at the temperature of boiling water, and does not possess any unpleasant odour or flavour.

Sesame Oil, or Gingelly oil, known also by the names of Teel oil and Benne oil, although not the same as the oil of Ben or Behen, is obtained from the seeds of *Sesamum indicum* (*Orientale*, Linn.), a plant indigenous to India, and largely cultivated in tropical and semi-tropical climates; it grows to the height of from 2 to 4 feet. A great deal of seed is imported into Europe from Ceylon and Egypt, the oil being extracted for the most part at Marseilles and other places in the South of France. The seed contains from 45 to 50 per cent. of oil, 30 per cent. of which may be extracted by simple pressure, and the remainder with the assistance of steam and hot water. The seed grown in the Levant yields from 5 to 6 per cent. more oil than the Indian seed. This oil consists of olein to the extent of 76 per cent., together with stearin, palmitin, and myristin, and has a sp. gr. of about 0.924; it has very little odour, and a mild, agreeable flavour; it is largely used in France for culinary purposes, and is by no means a bad substitute for olive oil, however applied. In India, as well as in China, both the seed and oil are used for edible purposes, the pressed cake, after the extraction of the oil, being also sometimes consumed as food by the poorer classes. It is a very common adulterant of olive oil.

The German sesame or Camelina oil is of another and inferior description, obtained from the small yellow or ruddy seeds of *Camelina sativa*

(*Myagrum sativum*, Linn.), and is used for burning and for painting purposes.

Oil of Ben or Behen, obtained from the seeds of the *Moringa oleifera*, or *Guilandina moringa*, has but little tendency to become rancid, and is a valuable oil for the extraction of perfume from flowers.

Ram-til Oil, Guizot Oil, or Niger Oil.—This oil consists of the glycerides of oleic, palmitic, and myristic acids, as well as of an acid of the linoleic series. It is obtained from the seeds of *Guizotea oleifera*, which is termed "Niger seed" when imported from Africa, and Ram-til, or Kersonee, when imported from Bengal. The plant is cultivated in Abyssinia and in many parts of India. The seed yields from 35 to 40 per cent. of oil, which is mostly expressed in Germany or England, cold pressure yielding 20 to 25 per cent. of oil. The oil, which has a sp. gr. of 0.924, possesses slight drying properties, and contains but little stearin or palmitin; it is a limpid, clear, pale-coloured sweet oil, and is used by the lower classes of India for edible purposes. The oil is employed in England in the manufacture of soft soap.

Arachis Oil (Ground-nut oil, Earth nut, Pea-nut) is obtained from the nuts of *Arachis hypogæa*, a plant which is extensively cultivated in tropical and semi-tropical climates, and possesses this peculiar property, that when the flowers wither the stalk of the ovary elongates, and bending downwards forces the young seed-pod under the ground; hence the derivation of the name ground-nut. The plant requires a good soil, the seed is sown in October or November, and the first crop of nuts for eating in the green state is ready in the following April; the nuts are ripe in July or August.

Ground-nut meal is very nutritious, contains a large amount of nitrogenous constituents, and ranks with lentils as an article of diet. The plant, which is indigenous to America, is cultivated in various countries for the sake of the oil which it yields, amounting to about 40 per cent.; this is principally extracted in France. The nuts are cleaned and decorticated, and the kernels crushed and pressed, the oil being filtered through bags. The oil first expressed, amounting to about 18 per cent., has a sp. gr. of 0.916 to 0.920, and is used for edible purposes.

Arachis oil is of a pale greenish colour, has a nutty flavour and an odour resembling that of peas. Its chemical constitution is peculiar, the glycerides of palmitic and oleic acids being to some extent replaced by those of arachidic acid, $C_{20}H_{40}O_2$, and hypogæic acid, $C_{16}H_{30}O_2$. Arachis oil is employed as a substitute for olive oil, and is sometimes passed as such. It is largely employed for adulterating olive oil, in which it may sometimes be detected by its peculiar flavour. It also gives rise to a reddish coloration when equal measures of the oil and nitric acid, sp. gr. 1.4 (free from nitrous compounds), are shaken together. Its presence, according to Allen, may be detected with greater certainty by employing a modification of Renard's process * based on the isolation of arachidic acid. This acid closely resembles in many respects stearic acid, but it has a higher melting point, 75° C. (169° F.), which serves to distinguish it.

Cocum Butter.—This fat, known under a variety of names, cokum, kokum, Goa butter, and mangosteen oil, is a solid and rather friable fat of a white or greenish yellow colour, and a somewhat agreeable odour; it is obtained from the seeds of *Garcinea indica*, a native of Western India, and consists of stearin, olein, and myristin. A similar description of fat, known as gamboge butter, is obtained from *Garcinea pictoria*, a tree growing in the forests of the hilly districts of India, sometimes at a height of 3000 feet above the level of the sea. These fats are used for lamps, and are sometimes consumed as food by the poorer natives as a substitute for ghee.

* Allen's "Organic Analysis," ii. 106.

Neem Oil, or **Margosa Oil**, is obtained from the fruit of a species of margosa, *Melia azedarachia;* it has a bitter disagreeable flavour, and is used by native physicians for medicinal purposes.

Myrtle Wax is not properly speaking a wax, but a fatty body containing about 13 per cent. of glycerol, and is obtained from the berries of several species of Myrica (*cerifera, serrata, &c.*); it has a sp. gr. of 0.995, and an exceptionally low melting point as compared with waxes, being not more than 40.5° C. (107° F.); the solidifying point corresponds closely with the melting point, the difference between them not being more than about 1° C. This so-called wax is extensively employed in the adulteration of beeswax and in the manufacture of soap and candles.

Japan Wax.—This is also a fat containing nearly the same amount of glycerol as myrtle wax. It is obtained from the berries of several species of Rhus, chiefly from *Rhus succedanea*, which flourishes in the western provinces of Japan and is cultivated in California. Its melting point is a little higher than that of myrtle wax, 51°–53° C. (124°–127° F.), its solidifying point being about 40° C. (96° F.), and its sp. gr. at 15.5° C. (60° F.) is about 0.990. It is used for very much the same purposes as myrtle wax.

Crab or Carapa Oil is a vegetable butter obtained from *Carapa guianensis*, a tree growing in British Guiana and in Western Africa, and also from *Carapa moluccensis*, growing in India, Ceylon, and the Moluccas. The seeds yield by heat and pressure 40–50 per cent. of solid fat, having a strong bitter flavour; it consists chiefly of palmitin, with some olein and stearin; it melts at 73.5°–77° C. (164°–170° F.), and solidifies at 64.5° C. (148° F.). It has a sickly and very persistent odour which greatly interferes with its usefulness, as the means usually employed for deodorising are in this case ineffectual. It is used by the natives as a pomade to prevent the attacks of insects.

Vegetable Tallow.—There are a considerable number of trees dispersed over Asia and Africa that produce fatty bodies of the consistency of tallow. One of the most important of these is the tallow tree (*Stillingia sebifera*), which is cultivated in several provinces of China and to some extent in the north-east of India. This tree produces a white brittle fat known as Chinese tallow, which forms a thick hard layer upon the surface of the seeds; this fatty substance consists chiefly of palmitin with a small proportion of olein, and has a melting point of about 44° C. (111° F.). The nuts, after being pounded in a mortar to loosen the seeds, are placed in wooden colanders and the fat is melted off by steam. The operation of steaming and straining through bamboo sieves is repeated until the whole of the fat has been removed; this is then purified by remelting and is poured into tubs, in which it is allowed to solidify in masses of about 80 lbs. A fluid oil is also obtained from the crushed kernels by boiling with water and pressing; this oil possesses some drying properties, and is used in the preparation of varnish and for burning in lamps.

Candle-nut Oil is obtained from the nuts of *Aleurites triloba*, which is cultivated in tropical climates, the kernels yielding about 55 per cent. of a sweet and limpid oil, which remains fluid at 0° C. (32° F.). The oil possesses medicinal properties of a character similar to those of castor oil; it consists of the glycerides of linoleic, myristic, palmitic, and oleic acids. The natives of the South Sea Islands are in the habit of placing the nuts on the end of a stick and using them as candles or torches, and from this circumstance the oil derives its name.

ANIMAL FATS.

Tallow and Lard are two of the most important animal fats, and constituted for many years almost the only source of supply of solid fats for

manufacturing purposes. Under the head of beef and mutton tallow is included the fat of other ruminants besides that of the ox and the sheep. Russian tallow consists mainly of the fat of oxen that are fed for the greater part of the year on dry food, which it is well known tends to increase the firmness of the fat of animals. Russian tallow has had the credit of having been melted and packed with more than ordinary care; it is imported in casks adorned with various cabalistic brands, and although neither these nor the celebrated PYC mark could always be depended on as a guarantee of quality, yet this particular description of tallow has for many years enjoyed a very high reputation (in some degree deservedly so), which it still retains to a great extent. Very large quantities of both beef and mutton tallow are now, however, received from Australia of a much better quality than was the case some years ago, so that the difference between these and the Russian is in many cases scarcely distinguishable.

As regards chemical composition, tallow and lard are very similar, consisting of the glycerides of stearic, oleic, and palmitic acids, olein and stearin being the chief constituents. Tallow generally contains some free fatty acid, the amount, when the tallow is not adulterated, depending to a great extent on its age.

Since the establishment of the enormous trade now carried on in factitious butters, beef fat is divided into several qualities, some of which are sold under different names, and are not recognised as tallow; a very fine quality melted at a low temperature from caul fat is described as "butter stock," from which is obtained by pressure oleo-oil and oleo-stearin, the term tallow being reserved for inferior qualities.

Tallow usually contains a little water and is liable to be adulterated with mineral matters, as well as with starch, inferior descriptions of fat, and especially with cotton-seed stearin.

For detecting such admixtures the tallow should be dissolved in light petroleum or other solvent, and the residue, when washed with a little ether and dried, should be examined for starch, cellular tissue, and other organic impurities. The mineral substances to be more particularly searched for in the ash left after burning off the organic matter are lime, the presence of which may be due to admixture with whiting or a lime soap, and phosphate of lime, which may have been added in the form of bone fat. The addition of cotton-seed stearin may be detected by the silver nitrate test as improved by Milliau, and also by the iodine absorption test, a description of both of which has already been given (p. 34).

In France, the method adopted for ascertaining the quality of tallow is that known as Dalican's, which depends on the determination of the solidifying point of the fatty acids, which from a genuine tallow should not be lower than 44° C. (111° F.). The fatty acids may be separated by saponifying the tallow with an alcoholic solution of potash; when the saponification is complete, the alcohol is evaporated, and the residual soap dissolved in hot water and decomposed by the addition of sulphuric acid; after being well boiled with water the fatty acids are collected and filtered through paper. It has been found that when the solidifying point is 44° C. (111° F.) the percentage of solid fatty acid (stearic) in the tallow amounts to 47.5 per cent.; if the solidifying point is as low as 40° C. (104° F.) the solid fatty acids in the tallow will not be more than 35.15 per cent.; whilst if the solidifying point is as high as 50° C. (122° F.) the solid fatty acids will amount to 75.05 per cent., and there is a table showing the percentage of fatty acids for intermediate temperatures. Finkener remarks that accuracy can only be attained by the use of a considerable quantity of fatty acids and by very slow cooling, and he recommends the employment of a globular flask 45 mm. in diameter, carrying a thermometer having its bulb in the centre of the flask, which is to

be surrounded with wadding and allowed to cool slowly. In this way it is stated that the thermometer will remain stationary at the solidifying point for ten minutes.

In refining or "rendering" tallow, as it is termed, the cells containing the fatty matter are burst by the agency of heat, and the particles of melted fat flow together. This is sometimes effected by putting the tallow (cut in pieces) together with a little water in an open vessel placed over a fire; the mass is kept stirred up, and as the oil exudes the membranous tissue gradually shrinks and collects together; this, after being put into bags and subjected to pressure, forms the greaves or cracklings largely used for feeding dogs. A further amount of tallow may be obtained from this mass by treating it with some solvent, such as light petroleum or carbon bisulphide. Boiling the fat in open vessels gives rise to objectionable fumes, and is not so effectual as using a closed boiler to which steam is admitted for several hours at a pressure of 50–75 lbs. on the square inch. The rendering is sometimes carried out in a loosely closed lead-lined tank by boiling with steam at the ordinary pressure, together with water containing a small quantity of sulphuric acid.

Besides Russian and Australian tallow, a large quantity of beef tallow is imported from Rio de la Plata. Tallow oil or tallow olein is obtained by subjecting tallow to hydraulic pressure; it has a sp. gr. of about 0.916, and remains liquid until the temperature is reduced to 6° C. (43° F.).

Bone tallow or grease is prepared by boiling bones in an open vessel for twenty-four hours and skimming off the melted grease as it rises to the surface, or the bones are subjected to the action of steam in a closed vessel at a temperature of 138°–143° C. (280°–290° F.) for about three-quarters of an hour. "Bone oil" is a different material, obtained by condensing the volatile products evolved in the calcination of bones for the purpose of making animal charcoal, in which operation the gelatinous tissues are decomposed, resulting in the production of a very dark coloured oil of unpleasant odour.

Lard is the fat of swine, the quality of which depends not only on its purity but also on the part of the animal from which it is taken. The best lard (leaf lard) consists of the fat that surrounds the kidneys, the caul fat, and the fat that lies underneath the skin, which is firmer and less easily melted than the fat obtained from the abdominal viscera. Bladder lard should be of the best quality, melting at about 40° C. (105° F.), whilst the unselected fat, sometimes termed keg lard, melts at about 32° C. (90° F.). Neutral fat, made from the leaf fat of newly slaughtered animals, contains scarcely any free fatty acid, and is chiefly used in the manufacture of butter substitutes.

Lard is liable to be adulterated with the same class of substances as tallow, and to a still greater extent with cotton-seed stearin, which not unusually varies in quantity from 15 to 50 per cent. To such an extent is this the case, and so thoroughly is this admixture a recognised fact, that some of the largest American manufacturers of lard have abandoned the term refined lard as applied to this mixture, and have substituted that of "compound" lard.

Good American lard should contain no salt, and less than 1 per cent. of water.

The annual production of lard in the United States has been estimated at upwards of 250,000 tons, about one-half of which is "compound" lard; the exports amount to 147,000 tons, 40 per cent. of which is compound lard, which, supposing it to contain 25 per cent. of cotton-seed stearin, would account for the disposal of a very large proportion of the cotton-seed oil produced.

Lard oil is the limpid and nearly colourless oil obtained by subjecting lard to pressure, the more solid portions which are left behind constituting what is known as "lard stearin"; the proportion which the oil expressed bears to the stearin depends to a great extent on the temperature at which the pressure takes place. Lard oil consists of olein with variable proportions of palmitin and stearin. Its sp. gr. is about 0.915 at 15.5° C. (60° F.). It is chiefly used in this country as a lubricant, but it is employed in America for lighthouse lamps. It is liable to be adulterated with a variety of oils of vegetable origin, such as cotton-seed oil, rape oil, arachis oil, and cocoa-nut olein, and it is consequently necessary that samples under examination should be subjected to most of the tests given for oils and fats, attention being particularly directed to the spectroscopic observation for absorption bands, inasmuch as a genuine oil should give no trace of such bands; the iodine absorption test and Milliau's silver nitrate test for cotton-seed oil are also of especial service in the examination of lard oil.

Whale Oil—Train Oil.—The use of this oil for illuminating purposes has of late years diminished to such an extent that, as regards this particular application, the oil cannot be considered as possessing nearly the same importance as was formerly the case, mineral oils having been to a great extent substituted for it. The term whale is frequently used in a somewhat indefinite manner, as representing any marine animal belonging to the order Cetaceæ, one of the true dolphins, *Delphinis tursio*, which is about 8 feet in length, being sometimes described as a small bottle-nosed whale.

The whales producing whalebone belong to the sub-order Mystacoceti, and the toothed whales to the sub-order Odontoceti.

Under Mystacoceti are included the Greenland or Arctic right whale (*Balæna mysticetus*), belonging to the polar seas; it is 40–50 feet in length, and yields the largest amount of oil. The southern right whale (*Balæna australis*), of which there are several species, inhabits the temperate seas of both the northern and southern hemispheres. The humpbacked whale (*Balænoptera boops*) is found in the North Atlantic and North and South Pacific Oceans. The rorqual or fin whale, belonging to the genus Balænoptera, is found in all seas except in the Arctic and Antarctic regions, the common rorqual (*B. musculus*) being 65–70 feet in length. The blue whale (*Balænoptera sibbaldii*) is the largest of all known animals, attaining a length of 80–85 feet.

The blubber, which consists of the dense fat several inches in thickness, lying beneath the skin, is cut in pieces, and stowed away in the oil tanks, and the oil subsequently extracted by boiling with water. The animal matters attached to the blubber undergo incipient decomposition during the voyage, and this, although it assists the extraction of the oil by causing the cellular tissue of the blubber to become so disintegrated that the oil readily exudes, produces at the same time a very nauseous odour, arising from the formation of a glyceride of valeric acid.

The term train oil properly belongs to the oil obtained from the Greenland whale, but it is commonly used in a much wider sense, including the oil derived from any of the marine mammals, and is sometimes applied to certain fish oils.

The oil is heated to the temperature of boiling water, in order to separate the impurities held in suspension, which after standing for some time are deposited, the oil when clear being drawn off. A Greenland whale will on an average yield about 15 tons of oil and 15 cwt. of whalebone. Owing to the large number of ships engaged in the trade, and the greater ease with which the animals are now caught by means of harpoons fired from a gun, the number of these marine mammals is gradually decreasing. The sp. gr. of whale oil varies from 0.920 to 0.931, and its chemical

constitution is of a somewhat indefinite character. Besides other glycerides, it contains variable proportions of a glyceride of valeric acid.

To the sub-order Odontoceti belongs the sperm whale (*Physeter macrocephalus*), to which allusion has already been made as yielding spermaceti. The sperm whale is captured in all tropical seas, and as much as 60 barrels of oil (equal to 10 tons) is sometimes obtained from a single whale. The oil is procured from the cavities in the head and also from the blubber, which is sometimes as much as 18 inches in thickness. Sperm oil has a very low sp. gr., 0.879–0.884, at 15.5° C. (60° F.). It has very little tendency to become rancid, and its viscosity is but slightly altered by variations in temperature. It is one of the finest oils for lubricating light machinery running at high velocities, such as the spindles of cotton machinery. The price it commands is still comparatively high; this has, however, been greatly reduced within the last ten years, owing to the competition of cheaper oils. Sperm oil is not a glyceride, but yields on saponification with caustic potash some of the higher alcohols, chiefly dodecatyl alcohol, together with oleate, as other salts of potash. By agitating the saponified product with ether, these higher alcohols are dissolved, and may be separated by drawing off the ethereal solution and evaporating the ether. One of the acids occurring in sperm oil, physetoleic acid, $C_{16}H_{30}O_2$, is identical in composition with hypogæic acid, but differs from it in not yielding sebacic acid on destructive distillation.

An oil of very similar character to sperm oil is obtained from the Dœgling, or bottle-nosed whale, known in commerce as Arctic sperm oil. This whale (*Hyperoodon rostratus*) abounds in summer in the northern seas, yielding an oil which is nearly equal to sperm in its lubricating properties. It is only within the last eight or nine years that much attention has been paid to this oil, which originally commanded a high price, but its value has since fallen to one-third of that formerly obtained for it. As regards its chemical composition, the results produced by the application of the usual tests so closely resemble those obtained from sperm oil, that practically the two oils are scarcely distinguishable from each other. It consists chiefly of an ethereal salt of a higher monatomic alcohol, dodecatyl dœglate, and yields on saponification dodecatyl alcohol, $C_{12}H_{25}.OH$, and dœglic acid, $C_{19}H_{36}O_2$.

Sperm oil is very liable to be adulterated with lower-priced oils, and hence it is necessary that commercial samples should be subjected to a very careful examination on the following points:—1. Specific gravity, and viscosity at different temperatures. 2. Its saponification equivalent should be determined; that of sperm and bottle-nose oils being considerably higher (with the exception of some samples of shark-liver oil) than other oils that are likely to be employed in adulterating sperm. Sperm or dœgling oil only requires from 12.3 to 14.3 per cent. of potash, KOH, for complete saponification, whilst the fixed oils generally require from 17 to 19.7 per cent. 3. The amount of the constituents in the products of saponification capable of being dissolved by ether should also be ascertained, and the character of the residue left on evaporation of the ether investigated. Sperm oil does not usually yield more than from 60 to 63 per cent. of insoluble fatty acids, and about 41 per cent. of ether residue, whilst animal and vegetable oils, with very few exceptions, yield about 95 per cent. of insoluble fatty acids, and not more than about 2 per cent. soluble in ether.

Seal Oil is obtained from the blubber of several species of Phoca, the capture of which forms one of the most important industries of Newfoundland. The seals resort to the ice-fields in February when the young seals commence their existence, and where they remain for about six weeks, and then take to the water. The young seals are taken when they are about four or five weeks old, by which time the skin and fat will weigh from

40 to 50 lbs., the fat beneath the skin being three or four inches in thickness. Seals may be divided from a commercial point of view into two kinds—Hair seals and Fur seals. The Hair seals do not possess the close velvety short fur that renders the Fur seals so valuable; the skins of the Hair seals being simply converted into leather. The skins, and the blubber, which surrounds the entire body, are removed while the animal is still warm. The remainder of the carcase is not of sufficient value to be worth carriage. The blubber is removed from the skin and piled up in large vats with perforated sides, through which the oil which exudes from the pressure of the mass passes into lead-lined wooden tanks. After several weeks the quantity of this oil (which is of the finest description, and known as pale seal oil) will amount to as much as from 50 to 70 per cent. of the entire quantity. The blubber is then cut in pieces by machinery and boiled with water or steamed to extract the remainder of the oil, which after bleaching by exposure to the sun in glass-covered tanks is barrelled off for exportation.

Seal oil consists of the glycerides of stearic, palmitic, and physetoleic acid, together with a small quantity of oleic and valeric acids. It has usually a sp. gr. of about 0.924–0.929, but is sometimes lower than 0.924. It is employed for burning in lamps as well as other purposes, and is said to be used for the adulteration of cod-liver oil.

Shark-liver Oil.—Shark oil.—The basking shark (*Selache maxima*) is the largest fish in the North Atlantic ocean, attaining a length of 30 feet. It is taken on the coast of Norway and on the west coast of Ireland, but the number is considered to be diminishing. The liver yields a very large quantity of oil, as much as from 150 to 240 gallons being obtainable from a single fish. This oil is frequently stated to have a very low density, 0.870 to 0.880, but it is probable that the samples from the examination of which such numbers were obtained were adulterated. The sp. gr. of a genuine oil is stated by Allen (who took some trouble in the determination of this point) to be from 0.911 to 0.929. This oil contains a large proportion of unsaponifiable matter, consisting to a great extent of cholestrol (cholrestin), and consequently, after treating with alkali, leaves a large amount of residue soluble in ether. The oil is said to be used as an adulterant of cod-liver oil, and to be sometimes passed off as such.

Menhaden Oil is obtained from *Alosa menhaden*, a fish found on the Atlantic coast of North America, and allied to the herring, the chad, and the pilchard. It migrates in shoals from the Gulf stream, reaching the coast of New Jersey in April, and that of Maine in May or June, remaining there until October or November. The fish is about 12 inches in length, and is caught in seines. To obtain the oil the fish are boiled with steam for about twenty minutes, and then subjected to pressure. The oil is placed in settling tanks, and when the matter held in suspension has had time to deposit, is drawn off and filtered. The oil, which has a sp. gr. of 0.927 to 0.933, is used for burning in miners' lamps and for dressing leather, and also, as it possesses drying properties, for adulterating linseed oil. The valuable properties of this oil have not been generally recognised until within the last few years. It is stated that the fish are converted into American sardines.

SECTION II.

STEARINE.

BY

JOHN McARTHUR.

STEARINE, in a chemical sense, is the name of the ethereal salt of glycerin, present in all neutral animal fats. Industrially and commercially, it is applied to the solid mixture of fatty acids, principally palmitic and stearic, obtained in the decomposition of fats, and employed for the making of candles, but the name more correctly describes the hard fat obtained from neutral fats by pressing, and is occasionally used in this sense.

The stearine industry owes its origin to the researches of Chevreul on the constitution of fatty compounds, and the action of alkalies and acids on them; these researches were commenced in 1811, and completely published in 1823, under the title of "Récherches Chimiques sur les Corps Gras d'Origine Animale." It is to others, however, that the honour is due of having successfully carried out the industrial application of Chevreul's discoveries.

From the many names of those who have assisted in the development and advancement of this industry, those of M. de Milly in France, and Mr. G. F. Wilson, F.R.S., of Price's Patent Candle Company, in this country, may be mentioned as deserving of special notice.

Prior to the publication of Chevreul's investigations, Braconnot had proved that fats consisted of a solid and a liquid part; but it was generally supposed that these components were simple substances, and that when the fat was acted on by an alkali, as in the making of soap, direct union of the alkali and the fatty body took place. Chevreul showed, however, that fats are really compound substances, yielding, on saponification, fatty acids, which combine with the alkali, whilst glycerin or glycerol is liberated. He showed further, that the fatty acids, resulting from the decomposition of the soap, had a higher melting point than the fatty compound whence they were derived; which was a consideration of much importance, when the acids were to be employed for the making of candles. Their value was also increased by the removal of the glycerin.

Chevreul no doubt realised the industrial importance of his discoveries, and in January 1825, conjointly with Gay-Lussac, he applied for a patent dealing with the decomposition of fats, and the employment of the fatty acids for the making of candles; this process consisted in the saponification of the fat with caustic soda or potash, and the use of alcohol for the separation of the fatty acids. Candles made from the fatty acids, however, were very inferior as regards their burning, and the process was never carried out industrially. Another process, patented a few months later in the name of Moses Poole,* but attributed to Gay-Lussac, was also unsuccessful practically. It consisted in the saponification of the fat by an alkali, and the distillation

* Eng. Patent, No. 5183, 1825.

and pressing of the fatty acids. About the same time, Cambacérès also made an unsuccessful attempt to prepare fatty acids suitable for candles.

To MM. de Milly and Motard the credit is due of overcoming the practical difficulties, and establishing this important industry on a satisfactory basis. In 1831, they made known their process of lime saponification, and having started a factory for carrying it out, were able to produce their "Bougies de l'Étoile," the name by which the candles of M. de Milly's firm are still known.

THE RAW MATERIALS EMPLOYED, AND THEIR VALUATION.

The principal fats employed are tallow, palm oil, and grease of various kinds; the last named includes, besides "melted" fats, and others of a similar nature, the solid part from the pressing of animal fats, known as "grease stearine." At the commencement of the industry, and for some time afterwards, tallow alone was used, but it became possible, by means of processes afterwards discovered, to work on lower class and strongly coloured fats, and obtain from them stearine of good quality.

Neutral animal fats consist substantially of tri-stearin and tri-olein, and palm oil, of tri-palmitin and tri-olein.

The following table gives the percentages of glycerin and fatty acids theoretically obtainable from the three glycerides named.

Compound.	Formula.	Molecular Weight.	Glycerin.	Fatty Acids.	Total Yield.
Tri-palmitin	$C_3H_5(C_{16}H_{31}O_2)_3$	806	11.41	95.29	106.70
Tri-stearin	$C_3H_5(C_{18}H_{35}O_2)_3$	890	10.34	95.73	106.07
Tri-olein	$C_3H_5(C_{18}H_{33}O_2)_3$	884	10.41	95.70	106.11

The value of a fat to the stearine manufacturer obviously depends on the percentage of solid acids which it will yield, at the same time it is important that it should be capable of yielding a large percentage of glycerin. The colour and smell have also to be considered, when the fat is intended for the making of "saponified" stearine.

The setting point of the fatty acids (or "titre," as it is commercially called), when taken in connection with the results of the manufacturing process, affords the means of estimating the yield of stearine obtainable. For its determination, the fatty acids are first obtained by saponifying a small quantity of the fat, in a porcelain basin, by means of alcoholic potash, dissolving the soap in water, and decomposing it, by heating with dilute sulphuric acid. After washing and drying, the melted fatty acids are transferred to a narrow test-tube, and stirred with a delicately graduated thermometer, until a point is reached when the mercury in the thermometer remains stationary for some seconds, which is recorded as the "setting point."

The theoretical yield of glycerin may be obtained from a determination of the percentage of neutral fat. The neutral fat (or rather the *acid* fat) may be conveniently estimated by titrating, with a standard alcoholic solution of alkali in presence of phenolphthalein, a known weight of the raw material, dissolved in a mixture of alcohol and light petroleum. From the quantity of alkali used, the fatty acids are calculated, and the neutral fat taken by difference. By means of the table given above, the glycerin corresponding to the percentage of neutral fat present may be found. When the presence of non-saponifiable matter in the fat is suspected, other means must be adopted for the determination of the neutral fat; for a description of these, we would refer to analytical works on the subject.

THE CONVERSION OF NEUTRAL FATS INTO FATTY ACIDS.

Three methods may be used for obtaining fatty acids from neutral fats:

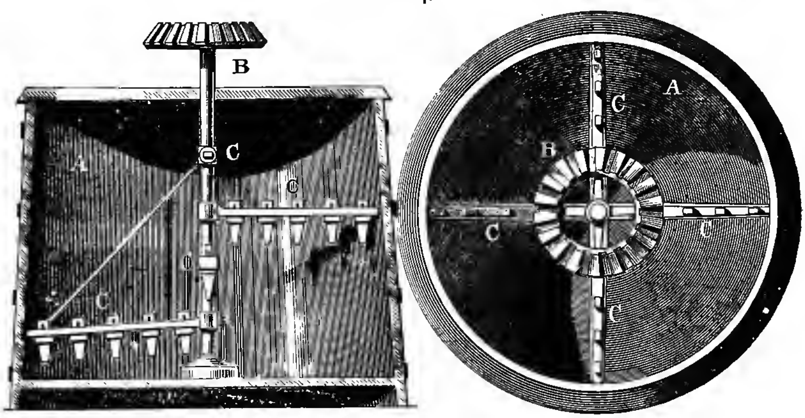
I. By saponification with lime or other base.
II. By decomposition with water alone.
III. By decomposition with sulphuric acid, generally followed by distillation.

I. Saponification with Lime.

Two different processes of saponification are or have been used.

A. *At the Ordinary Pressure.*—This is the process introduced by MM. de Milly and Motard, and formerly extensively used in most countries; it is now employed to a very limited extent only, if at all. The vessel used, Fig. 14, consists of a large wooden vat A, generally lined with lead, and capable of saponifying from one to five tons of fat. It is provided with a steam pipe,

FIG. 14.



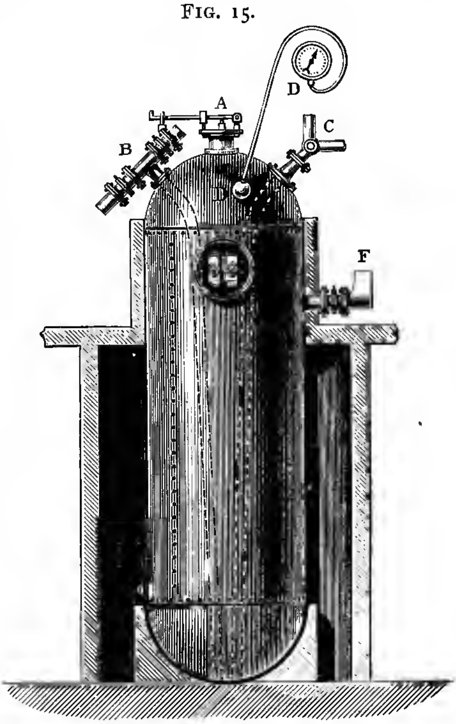
Apparatus for Lime Saponification (section and plan).

which reaches to the bottom of the vat, and terminates in a perforated coil. A strong shaft B, carrying four arms C, is supported in the centre of the vat, and set in motion, generally by steam power. Formerly, the necessary mixing was done by hand, by means of strong wooden staves. The fat—tallow, for instance—is introduced with about its own weight of water, and the steam turned on. A quantity of lime corresponding to from 14 to 15 per cent. of the fat, is then made into a "milk" with water, and added to the melted tallow. The quantity of lime, theoretically required for the saponification (assuming the tallow to be composed of equal parts of tri-stearin and tri-olein) is only 9.47 per cent.; but although a smaller quantity than 14 per cent. might be used, it is necessary to have a considerable quantity in excess of the theoretical amount, in order to allow for the impurities which the lime always contains, and to ensure complete saponification. The milk of lime having been added, the saponification commences at once, and is facilitated by the mixing. The passing of the steam is continued throughout the operation, which is generally complete after about eight hours, when the lime soap appears as a hard white mass. After having been allowed to cool, the dark-coloured glycerin water (or "sweet water," as it is technically called in this country) is run off, by means of a stopcock inserted at the bottom of the vat, and the lime soap, when it has been

broken up, is ready for decomposition. When wooden vats are used which are not lead-lined, it is necessary to transfer the lime soap to a special lead-lined vessel, for its decomposition. The decomposition is effected by sulphuric acid of about 1.20 sp. gr., the quantity required being considerably greater than that theoretically necessary for the lime present.

After the addition of the acid, the agitator is set in motion, the steam turned on, and the heating continued until the soap is completely decomposed. The liberated fatty acids rise to the surface, whilst the sulphate of lime is precipitated. The former are transferred to a lead-lined tank, in which they are washed, first with acidified water, and then several times with pure water, in order to remove the last traces of sulphuric acid. They are then ready for crystallisation and pressing, or for further treatment by the processes to be described.

FIG. 15.



M. de Milly's Autoclave.

This method is attended by several disadvantages, principally due to the large quantity of lime required for the saponification. The "sweet water" cannot be completely removed, the breaking up of the lime soap is troublesome, and the cost of the acid necessary for its decomposition is considerable. Besides, the large mass of insoluble sulphate of lime formed retains some of the fatty acids, which can never be completely recovered.

B. *At a High Pressure, with a small quantity of Lime.*—The early stearine manufacturers, realising the disadvantages of their lime saponification process, made many attempts to improve it, especially in the direction of reducing the quantity of lime required. As early as 1834, MM. de Milly and Motard endeavoured to effect the decomposition of fats in an autoclave, but it was not until 1855 that M. de Milly, by the addition of a certain reduced percentage of lime, succeeded in carrying out the process industrially.* This process, with but few modifications of importance, is now perhaps more extensively employed than any other.

The vessel used, Fig. 15. is constructed on the principle of Papin's digester. It is made of copper, is cylindrical in form, dome-shaped at both ends, and sufficiently large to decompose from one to three tons of fat in one operation. The thickness of the metal depends on the diameter of the vessel, and the pressure to which it is to be subjected, but it generally ranges from about ½ to 1 inch. The vessel rests upon a substantial support, and is enclosed, throughout nearly its entire length, within a brickwork chamber, with the object of preventing loss of heat, and allowing easy access for any necessary repairs.

* Eng. Patent, No. 2740, 1856.

The "charge" consists generally of a mixture of three parts of fat, one part of water, and about 2 per cent. of lime (on the fat); but the proportions vary.

The melted fat, from which the suspended impurities have been removed by settling, is introduced through the charging pipe F, Fig. 15, which is generally funnel-shaped, and is provided with a stopcock. The lime is then weighed out, made into a "milk" with the required proportion of water, and run into the autoclave. The stopcock having been closed, high pressure steam is passed in through the pipe B, which extends to within an inch or two of the bottom of the vessel. The pressure gradually rises, and is maintained at about eight atmospheres (atmosphere excluded), corresponding to a temperature of 175° C. (348° F.) until the decomposition is considered to be practically complete. The heating is continued for from four to five hours, sometimes for eight hours, but even the longer period does not complete the decomposition, a few per cent. of neutral fat remaining undecomposed. The steam is generally allowed to escape, to some extent, in order to promote the mixing of the materials. The pressure is indicated by the gauge D, and is prevented from exceeding the limits of safety by the valve A. The lime combines with part of the fatty acids to form a lime soap, but the bulk of the fatty acids is in the free state, the glycerin remaining dissolved in the water.

Fig. 16.

Autoclave with Mechanical Agitator.

When the decomposition has been completed as far as possible, the steam is turned off, the temperature allowed to fall a little, the two-way cock C, opened, and the "sweet water" blown into a receiving tank. When the "sweet water" has been removed, the stopcock is again turned, and the mixture of fatty acids and lime soap is blown into an iron vessel lined with lead.

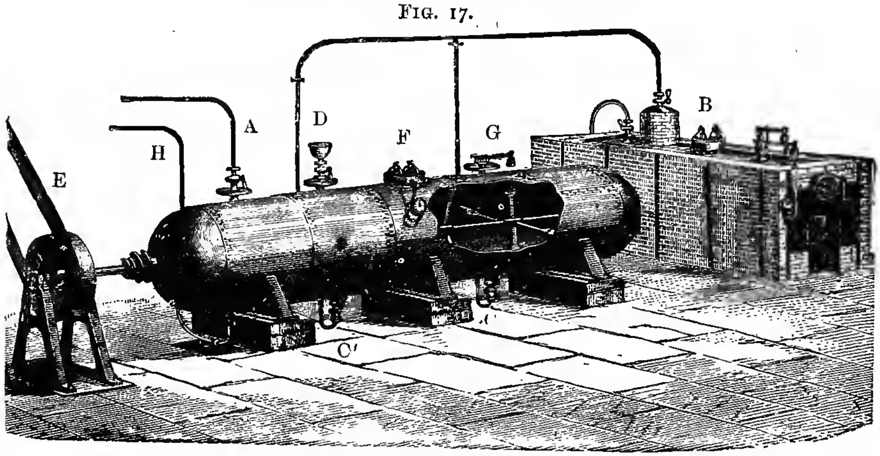
Some autoclaves are provided with one pipe only, fitted with a T-piece, which serves for the discharge of the mixture as well as for the introduction of the steam. In some cases the whole contents are blown into one tank, and the "sweet water" afterwards separated. The saponified fat having been washed two or three times with water to remove the "sweet water" which it retains, is then mixed with a quantity of diluted sulphuric acid, slightly in excess of that theoretically required to combine with the lime, and is boiled with open steam; after the boiling has been continued for an hour or so, the lime soap is decomposed, and the sulphate of lime and acid water are then removed from below. The fatty acids mechanically retained by the sulphate of lime are extracted by boiling up the mass with water, and are then skimmed off and added to the bulk. The

fatty acids, after having been washed with water, are ready for further treatment.

Many different theories have been advanced in order to explain the process of saponification with an insufficiency of lime, as just described. Some authorities suppose that the decomposition of the fat takes place in several stages, a basic soap being at first formed, which is decomposed by the water into an acid soap; the free lime, liberated for the moment, being then capable of acting on another quantity of neutral fat, &c. It seems more probable, however, that the decomposition of the fat is effected by the water alone, and that the presence of the lime merely facilitates the operation, by reducing the affinity of the fatty acids for the glycerin.

In this process of saponification, other bases are sometimes substituted for the lime. Hydrate of magnesia and oxide of zinc may be used with success. They are both more costly than lime, but, as weaker bases, they do not darken the fat to the same extent as lime, and they possess the great advantage of yielding "soaps" which are readily decomposed by acid, with formation of soluble salts; at the same time the loss of fatty acids is reduced.

FIG. 17.



L. Droux's Horizontal Autoclave with Mechanical Agitator.

Such substances as carbonate of magnesia, chalk, talc, &c., which are intended to act merely as "mechanical agents for opening up the molecules of the fat, and breaking through the albuminous film surrounding the same," have been patented by A. Marix,* as substitutes for lime and other bases.

Various modifications of M. de Milly's autoclave have been from time to time proposed, the most important being those which provide for the mixing of the contents of the vessel by mechanical means, some manufacturers believing that more perfect decomposition of the fat is thereby obtained.

Fig. 16 shows an autoclave constructed on this principle by P. Morâne. In the centre of the vessel a cylinder of copper is fixed, which is open below and closed above, with the exception of numerous perforations. Within the cylinder a stirrer is made to revolve, and, while doing so, an upward movement is communicated to the contents of the autoclave, which conveys them through the perforations of the cylinder. They are thus distributed, in the form of a spray, upon the sides of the autoclave, and flowing down, are again conveyed through the cylinder as before. In this way a constant agitation of the whole contents is maintained.

L. Droux has devised a *horizontal* autoclave, Fig. 17, with an arrange-

* Eng. Patent, No. 2349, 1883

ment for mechanical mixing, which is in use in certain factories. It consists of a cylindrical copper vessel, dome-shaped at both ends, like De Milly's. The "charge," composed of fat, water, and lime, is introduced through the pipe A. Steam is then passed in from the boiler B, entering the autoclave on its lower side by the pipes C and C′, and the stopcock at D is opened to allow the air to escape. The agitator, which consists of a strong copper shaft running from end to end of the vessel, and provided with eight paddles, is then set in motion by the pulley E, and made to revolve at the rate of about thirty revolutions per minute, the agitation being continued to the end of the operation; the pressure is regulated by the indications of the gauge F, and by the safety-valve G. When the saponification is supposed to be complete, the steam is turned off, the agitation stopped, and the contents blown out by the pipe H, into a suitable receiving vessel, where they are separated, and the soap decomposed.

L. Droux has devised also a *spherical* autoclave; the mixing of the contents is provided for by an agitator constructed on the principle of the one just described.

II. Decomposition by means of Water alone.

That decomposition of a neutral fat by water alone is possible chemically, is shown by the following equation, which represents the reaction with tristearin:

$$\underset{\text{Tristearin}}{C_3H_5(C_{18}H_{35}O_2)_3} + \underset{\text{Water}}{3H_2O} = \underset{\text{Glycerin}}{C_3H_5(OH)_3} + \underset{\text{Stearic acid.}}{3C_{18}H_{36}O_2}.$$

Analogous reactions take place with tripalmitin and triolein.

The decomposition of the fat with water may be effected in two ways:

A. Heating under Pressure.

Tilghman, in America, was the first to discover, in 1854, that water under pressure is capable of dissociating neutral fats. Later in the same year, the fact was made known by Berthelot, in France, and by Melsens, in Belgium. Berthelot confined his attention to the scientific side of the discovery, whilst Tilghman endeavoured to apply it industrially.

*Tilghman's Apparatus,** Fig. 18, consists of a digester A, in which the fat, with about half its weight of water, is kept in an emulsified condition by the action of the perforated piston B. The pump C forces the emulsion of fat and water through the coils of iron pipe D, which are enclosed within the chamber E, the latter being heated by the fire F, to the "melting point of lead," 334° C. (633° F.). The heating of a given quantity of the mixture is continued for about ten minutes, a valve at G preventing the escape of the contents. The pump is then set in motion, the valve opened, and the contents, as they flow out, are cooled by passing through the worm G, and led through the pipe H to a suitable receiving vessel, where the fatty acids are separated from the "sweet water." Another quantity of fat and water is then subjected to the same treatment. This form of apparatus, on account of its many obvious defects, and the enormous pressure at which it was worked, was soon abandoned.

Melsens' Apparatus† consists of a horizontal boiler-shaped vessel of iron, lined with lead, which is heated in a carefully regulated furnace. The mixture of fat and water is raised to a temperature of from 170°–205° C. (340°–400° F.), special means being employed to maintain the intimate contact of the two substances. The addition to the water of a quantity of

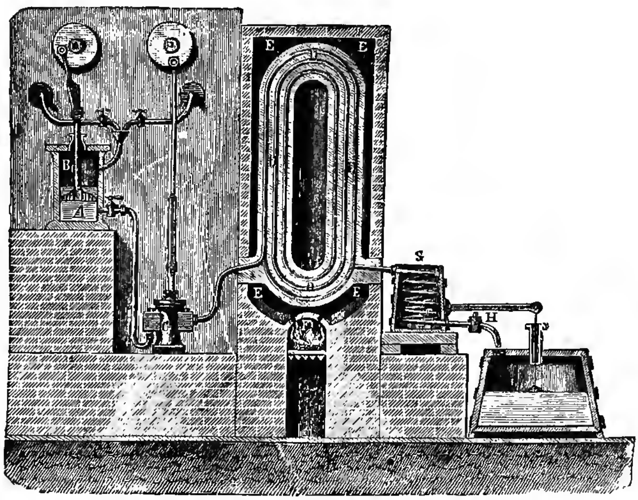
* Eng. Patent, No. 47, 1854. † Eng. Patent, No. 2666, 1854.

sulphuric acid, corresponding with 1 to 10 per cent. of the fat, facilitates the decomposition. This apparatus, although of more practical construction than Tilghman's, and capable of yielding fatty acids of better colour, was also abandoned, on account of the rapid destruction of the lead lining.

Wright and Fouché,* Renner,† De Roubaix, in 1866, and L. Droux, in the same year, also brought forward special forms of apparatus; but this process of aqueous decomposition has not hitherto met with much favour among stearine manufacturers, principally on account of the structural defects of the apparatus, and the consequent danger attending the use of the vessels at the high pressure to which they are necessarily subjected.

Lately, however, with the advance of mechanical science, these defects have to a great extent been remedied. Two forms of apparatus, those of L. Hugues and A. Michel, are now used in certain factories, and deserve notice.

FIG. 18.



Tilghman's Apparatus for the Decomposition of Fats by Water.

L. Hugues' Apparatus‡ is shown in Fig. 19: the figure represents also the mode in which the superfluous steam is utilised for the concentration of "sweet water." The autoclave A, made of very thick copper, is cylindrical in form, and of the same general construction as M. de Milly's. It is sufficiently large to decompose about one ton of fat in each operation. The fat and water having been introduced, high pressure steam is passed in through the pipe D, which descends to the bottom of the vessel, and is surrounded by a tube through which the contents are carried upwards, and their circulation thus assisted.

The steam is supplied from an independent boiler, and the pressure within the autoclave is automatically regulated, and kept at about 14 atmospheres for six or seven hours. Agitation of the contents of the autoclave is promoted also by allowing the steam to circulate quietly through the apparatus during the decomposition.

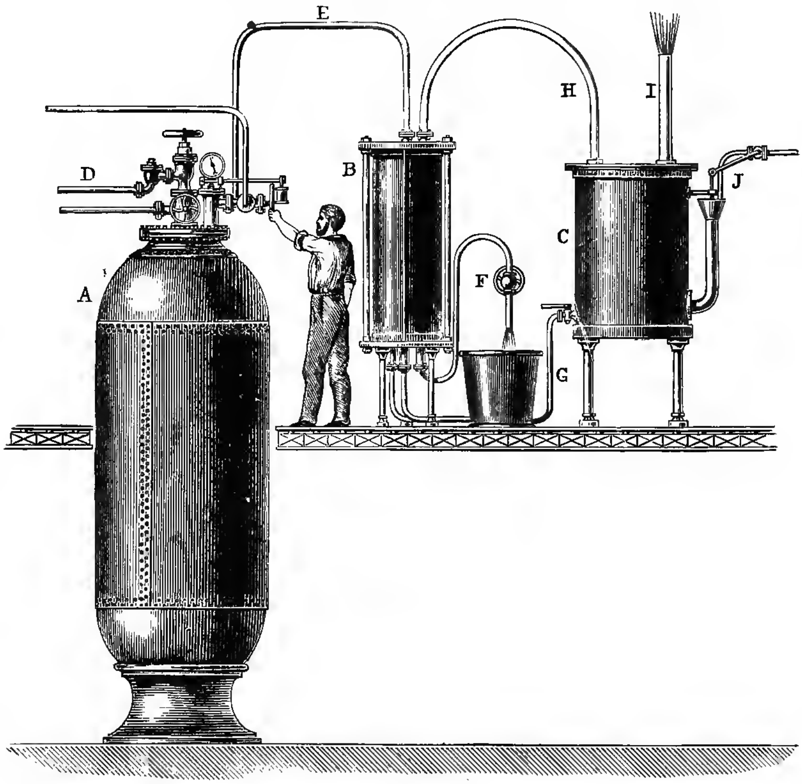
The steam leaves the autoclave by the pipe E, and is condensed by passing through a worm within the condenser B, the water formed running

* Eng. Patent, No. 894, 1857. † Eng. Patent, No. 1014, 1866.
‡ Eng. Patent, No. 6562, 1885; Fig. 5 of the specification.

off at F, the stopcock there being used to control the passage of the steam.

Meanwhile, a regulated volume of "sweet water," obtained from the decomposition of a previous quantity of fat, flows into a pipe at J, and after having been heated by passing through the vessel C, it flows through the pipe G into the condenser B, where it is concentrated to the desired specific gravity, and then run off from below. The steam resulting from the evaporation of the "sweet water" is led through the pipe H, to heat the vessel C, and the exhaust steam allowed to pass off at I.

FIG. 19.



L. Hugues' Apparatus for the Decomposition of Fats by Water.

A. Michel's Apparatus,* Fig. 20, consists of two autoclaves, capable of decomposing $2\frac{1}{2}$ tons of fat, and heated by fire-heat alone.

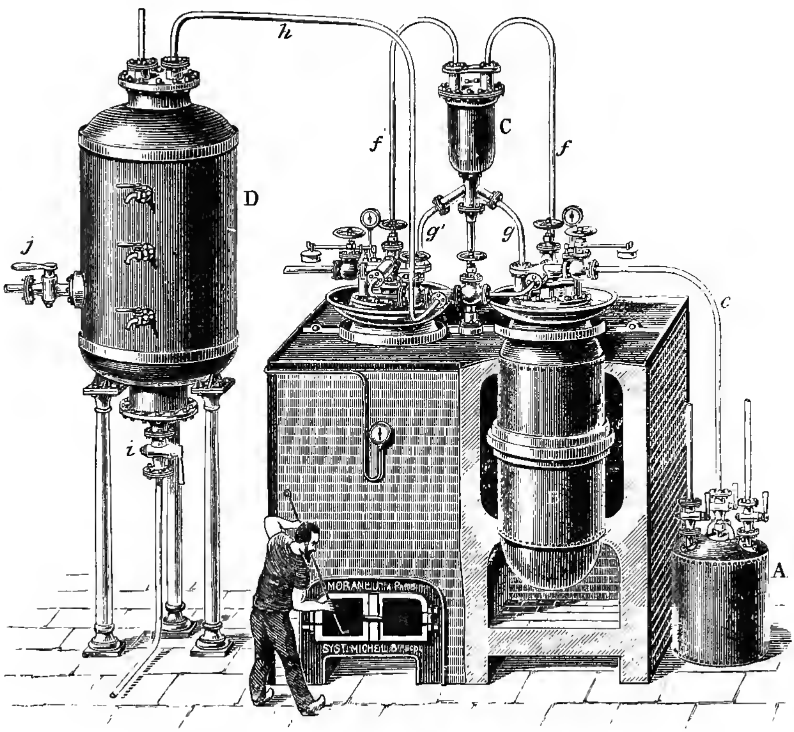
A mixture of about five parts of fat and one part of water is supplied to the two autoclaves B, by the monte-jus A, or by some similar means through the pipe *e*. Heat is then applied, and as the pressure within the autoclaves rises, the mixture of fat and water is forced through the pipes *f*, *f'* (which extend to the lower part of the autoclaves), to the vessel C. The temperature of this vessel being lower than that of the autoclaves, the mixture becomes colder, descends by the pipes, *g*, *g'*, and is again carried upwards, so that a constant circulation of the contents of the two autoclaves is maintained. The pressure is raised to from 15 to 16 atmospheres, and

* Eng. Patent, No. 8403. 1885.

kept at that point for about eight hours, when the mixture is discharged into the closed vessel D, through the pipe *h*; after standing for about half an hour to cause the fatty acids to separate from the "sweet water," the latter is drawn off, by opening the stopcock *i*, and received in a suitable vessel. The fatty acids pass direct by the pipe *j*, to a still for distillation, or they may be acidified, &c.

The principal advantage of the process of decomposition by water, under pressure, is economy, as the acid, as well as the base required in the process of lime saponification, is unnecessary. It is also claimed that the products are of better quality than those obtained by lime saponification.

FIG. 20.



A. Michel's Apparatus for the Decomposition of Fats by Water.

B. By Superheated Steam, at the ordinary Atmospheric Pressure.

In 1841, M. Dubrunfaut took out a patent* for a process, by which fats, when heated to their boiling points, in a current of steam, could be made to yield all the fatty acids which they were capable of producing. He pointed out also that by the aid of steam the distillation could be carried on at a lower temperature than without it.

In 1854, G. F. Wilson and G. Payne patented a process† for effecting the decomposition of neutral fats, and the distillation of the resulting glycerin and fatty acids, in one operation by means of superheated steam, and were successful in carrying out the process industrially.

* Under the name of Wm. Newton. Eng. Patent, No. 8854, 1841.

† Eng. Patent, No. 1624, 1854.

The fat is heated in a still like those used for the distillation of fatty acids. The temperature suitable for the decomposition ranges between 288° and 315° C. (550° and 600° F.); if it be lower than 288° C. (550° F.), the decomposition of the fat and the distillation of the products progress very slowly; on the other hand, if it be higher than 315° C. (600° F.), acrolein is produced as a decomposition product, and the fatty acids are darkened in colour. The success of the process depends on the care with which the temperature is regulated. The glycerin and fatty acids distil over together, and can be afterwards readily separated.

This process is now only of historical interest.

III. Decomposition by means of Sulphuric Acid.

The action of sulphuric acid on neutral fats has been investigated by many observers. As early as 1777, Achard worked on the subject, and noticed that the character of fats treated in this way was modified. Braconnot also studied the action of sulphuric and nitric acids, but it was reserved for Chevreul to show, in 1824, that fats on treatment with sulphuric acid, are decomposed into fatty acids and glycerin. The subject was still more fully investigated by Fremy, in 1836, who found that fatty oils, when mixed with an equal weight of sulphuric acid at a low temperature, became harder; and from the results of his experiments he concluded that sulphuric acid, in decomposing fats, forms sulphonated compounds with the acids of the fat and with the glycerin, and that these compounds are decomposed by water, more readily on boiling, into fatty acids, glycerin, and sulphuric acid.

The first attempt to employ this process industrially appears to have been made in 1840, by George Gwynne,* distillation in a vacuum being proposed for the purification of the fatty acids. The method, however, was not carried out commercially.

In the same year, George D. Clark † patented a process for acidifying fats *without* distillation, but the means employed for the purification of the fatty acids were defective. In both of these processes, the acid was applied to the fat at a low temperature. The process was not industrially successful until 1842, when W. C. Jones and G. F. Wilson made known their method ‡ for the distillation of fatty acids in a current of superheated steam. By combining the processes of acidification and distillation they were able to obtain fatty acids of good colour from even the darkest fats and oils. Their process consisted in *heating* the fat with 33 per cent. of sulphuric acid, and then boiling the fatty acids with water. The quantity of acid was subsequently reduced to 10, then to 6, and finally to from 3 to 4 per cent. by applying it at a temperature of 177° C. (350° F.).

General Process.—The process here described was formerly extensively applied to all kinds of dark neutral fats. It is now, however, confined to such raw fats as are capable of yielding only a small quantity of glycerin, and, as a process of purification, to fatty acids obtained by lime saponification, or aqueous decomposition.

The fat, after standing for some time in the molten state, to allow the suspended impurities to subside, is heated in a vessel, by means of a closed steam worm, in order to remove the water, the temperature of the fat being then raised to the desired point. In most factories the temperature employed ranges from 115° to 121° C. (240° to 250° F.), but in others it is as high as 166° C. (330° F.). The heated fat is then transferred to the "acidifier," in which the first stage of the operation is conducted. This is usually a

* Eng. Patent, No. 8423. † Eng. Patent, No. 8686.
‡ Eng. Patent, No. 9542.

boiler-shaped vessel, provided with a mechanical agitator, and is steam-jacketed. In those factories where a comparatively low temperature is employed, the vessel is generally constructed of iron, lined with lead; where a high temperature is used, the vessel and its connections are made of copper, and the fatty matter heated by a coil, through which superheated steam circulates. These vessels vary in size, having a capacity of from one to six tons of fat.

Sulphuric acid, of from 1.82 to 1.84 sp. gr., is added to the hot fat. The quantity of acid employed varies from 3 to about 6 per cent., according to the quality of the fat, and the temperature at which it is applied; it is allowed to act generally for from two to five or six hours, the agitation being continued. The first effect of the addition of the acid is the production of a large quantity of sulphurous acid, which, with other volatile decomposition products, is led from the vessel through a pipe where it meets a current of water for its absorption, the unabsorbed vapours being afterwards consumed in a furnace, or made to pass to a chimney. The fat meanwhile becomes dark in colour, with formation of a quantity of black, tarry matter, which remains suspended in the fatty acids. When a high temperature is employed, this solid appears more compact, and settles readily.

The neutral fatty matter—palm oil, for example—is converted into a mixture of sulpho-palmitic, sulpho-oleic, and sulpho-glyceric acids; the effect is the same when the process is applied to saponified fatty acids, but, as the neutral fatty matter present in these is small, little sulpho-glyceric acid is formed.

After standing at rest for an hour or two, to allow the tarry matter to settle, the mixture is transferred to another vessel, in which the second stage of the operation is carried out. The "acid bottoms," remaining in the "acidifier," are afterwards raked out, and the fatty acids retained by them allowed to drain away, and added to the bulk. The second stage of the process consists in the decomposition of the sulphonated compounds, by boiling with acidified water; the vessel in which the operation is conducted consists of a large, covered, wooden vat, lined with lead, and provided with a coil for supplying open steam. It contains a quantity of water to which some sulphuric acid has been added; this is raised to its boiling point, and the acidified material run in, and boiled with the water for from two to four hours. The boiling not only decomposes the sulphonated compounds, but cleanses the material from some of the tarry matter which often passes over from the "acidifier," and removes the sulphuric acid present; after settling, the water is run off, and the fatty acids are boiled a second time with water and a little acid, as before. The water is then removed, and they are ready for distillation.

The objection to this process, as a method for the decomposition of neutral fats, is, that the loss of glycerin is very considerable, and the glycerin obtained is of inferior quality; it is for these reasons that the process is now seldom used where the recovery of the glycerin is of importance. The loss of fatty acids, whether the process be applied to raw fats or to fatty acids, is also considerable, generally amounting to from 3 to 6 per cent., but it varies with the nature of the fatty matter and the conditions of the operation. The process, however, possesses certain advantages, which, in the opinion of some manufacturers, more than compensate for the objections named, leading them to apply it extensively to fatty acids.

1. An increased yield of solid fatty acids is obtained, generally considered to be due to the formation of a certain quantity of elaïdic acid. The yield of stearine obtained from tallow of good quality by lime saponification, or by aqueous decomposition, amounts to about 45 per cent.; but by the same processes, followed by acidification and distillation, the yield

is raised to about from 54 to 58 per cent.; the product, however, from the combined processes, has a somewhat lower setting point.

2. Dark-coloured fats, like palm oil, and dark greases generally, may be employed; when the acidification process is applied to the fatty acids and followed by distillation, a product of better colour is obtained than that from distilled fatty acids, which have *not* been acidified.

3. The stearine obtained by acidification and distillation (if the former process has been properly carried out) is more stable; so that, after having been kept for a year or two, it does not become yellow in colour, greasy to the touch, and "salvy" in smell, as the product from lime saponification and aqueous decomposition often does, unless it be of a comparatively high setting point.

De Milly's Process.—In 1867, M. de Milly suggested a modification of the ordinary process of decomposition with sulphuric acid, with the object of dispensing with the distillation of at least the bulk of the fatty acids.

The fat, heated to 120° C. (248° F.), is run through a wide pipe, where it meets with a stream of concentrated sulphuric acid, corresponding to about 6 per cent. on the fat, the contact of the acid with the fat being maintained for about two minutes, by allowing the mixture to flow through a gutter; it then falls into a vessel charged with boiling water, and is there subjected to prolonged boiling, which dissolves the glycerin with separation of the fatty acids. The acid water (containing the glycerin) is then removed, and the fatty acids purified. They are strongly coloured, but after cold, followed by hot, pressing, the colouring matter, being soluble in the oleic acid, is extracted, and the stearine is left quite white if the operation has been conducted with the necessary care. The oleic acid is then distilled, and the small quantity of solid acids which it contains recovered.

The great difficulty attending this process is to obtain the complete removal, by pressing, of any insoluble colouring matter which may have been formed by the action of the acid. But the principal objection to the process is due to the fact, that the short time during which the acid remains in contact with the fat does not allow of the formation of the large quantity of solid fatty acids which results from the prolonged treatment with acid in the ordinary process. For these reasons, the process is now no longer in use.

*Bock's Process.**—Dr. Bock, of Copenhagen, introduced some years ago a process, somewhat similar to that of M. de Milly, but yielding, it is claimed, a larger percentage of solid fatty acids, and of higher setting point, than "any known process."

According to Dr. Bock, neutral fatty compounds consist of exceedingly small globules of fat contained in membranous envelopes, and before the fat can be decomposed by any process, these envelopes must be opened up, or destroyed, so that the fat may be set free. These envelopes, in animal fats, are composed of cellular tissues, gelatin and albumin; in vegetable fats, of vegetable albumin and cellulose. When an alkali, as in the case of lime saponification, acts on a fat, the albuminous or proteid substances are dissolved, and the lime is then able to combine with the fatty acids, and liberate the glycerin. In the process of aqueous decomposition, the high temperature to which the fatty matter is exposed, opens up the envelopes, setting free the fat. When fats are acted on by concentrated sulphuric acid, the envelopes are charred, and the fat liberated for decomposition by the acid water.

* See Dingler's "Polytechnisches Journal," 1873, vol. ccviii. p. 230; also "Soap, Candles, Lubricants, and Glycerin," Lant Carpenter, 1885, p. 263.

It will be observed that Dr. Bock's theory of the action of sulphuric acid on fats, is quite opposed to the conclusion to which Fremy was led by his investigations; the former considering that the action is merely mechanical, whilst, in the opinion of the latter, it is purely chemical. All that is therefore required to effect what Dr. Bock calls "rational saponification," is to treat the fat with a quantity of sulphuric acid so adjusted that only the envelopes are attacked, and the fat allowed to escape in a condition in which it can be decomposed. The actual decomposition is effected by boiling the liberated fat, for several hours, with the necessary quantity of water, containing the theoretically required proportion (4 to $4\frac{1}{2}$ per cent. on the fat) of sulphuric acid. After allowing the mixture to settle, the acid water is removed, and the glycerin recovered. The fatty acids are black from the charred albuminous cells floating about in them, and may be purified by distillation.

The important feature of this process is, however, the removal of the colouring matter *without* distillation. In order to cause the charred cells to separate, the mass is oxidised by the action of some oxidising agent, whereby the specific gravity of the cells is raised from 0.9 to 1.3. After allowing the cells to settle, the fatty acids are removed, washed several times with water, and pressed cold, then hot. The stearine removed with the dark oil may be recovered by distillation and pressing.

This process has the advantage of simplicity, and as the operation may be completed in one, or at most two, vessels, no elaborate plant is required.

Many endeavours have been made to discover some chemical agent which, while possessing the advantages of sulphuric acid, might be free from its drawbacks, but so far they have not met with success.

Chloride of zinc, which in its action resembles sulphuric acid in certain respects, has been proposed. According to L. Krafft and Tessié du Motay, the fat is heated for some time at a temperature of from 150° to 200° C. (300° to 390° F.), with from 8 to 12 per cent. of the anhydrous salt. The mixture is then washed with hot water, or with water containing a little hydrochloric acid, and distilled. The product is said to possess all the properties of distilled fatty acids obtained by decomposition with sulphuric acid. The chloride of zinc may be recovered from the wash-waters.

THE DISTILLATION OF FATTY ACIDS.

Some of the early attempts which were made to distil fatty acids on an industrial scale have been already incidentally referred to.

The process of W. C. Jones and G. F. Wilson,* according to which the fatty acids obtained by the decomposition of the fat with sulphuric acid were distilled in a current of superheated steam, was the only one which met with success, and is now, with, in some cases, certain modifications, the recognised method of obtaining distilled fatty acids.

The principal object of the distillation is to improve the colour of the fatty acids. Accordingly, the process is universally applied to the fatty acids obtained by lime saponification or by aqueous decomposition, followed by acidification (unless Bock's process is used); some further treatment being necessary for the removal of the dark colour. Fatty acids which have not been acidified are also occasionally distilled.

Many different forms of stills and condensers have been suggested, each inventor claiming for his apparatus some special feature of advantage. The stills themselves are generally spherical or slightly elliptical in form,

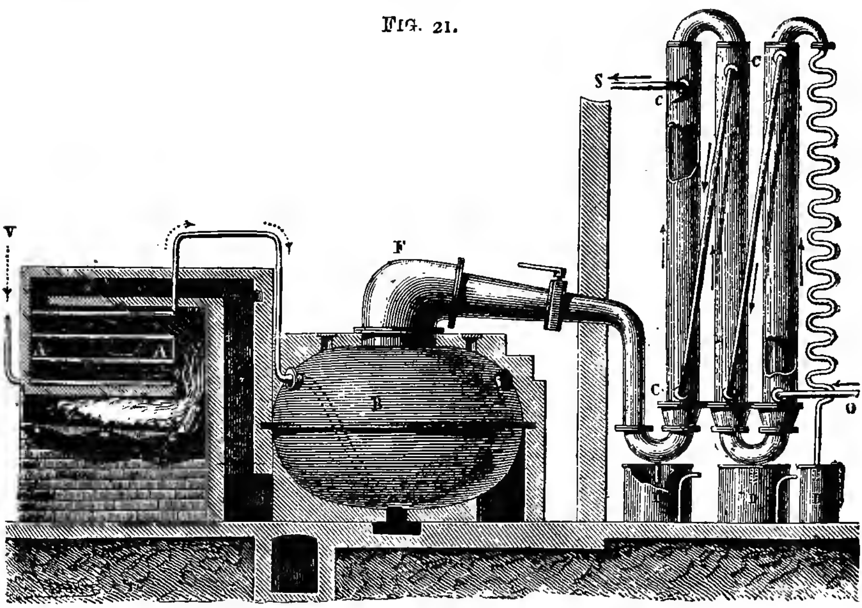
* Eng. Patent, No. 9542, 1842.

and have a distilling capacity of from one to six tons of fatty acids. Some of the condensers are constructed so that the products may be fractionated; in the case of others, the whole products are collected in the same vessel, and form one uniform distillate.

Fig. 21 represents a form of still, provided with upright condensers, which can be utilised for fractional distillation or otherwise.

It consists of a copper vessel B, enclosed within brickwork, so arranged that the bottom of the still may be heated by fire, if desired. The fatty acids to be distilled are introduced, and their temperature raised to nearly the point of distillation by means of the fire, and by steam. Direct exposure of the still to fire heat is sometimes entirely dispensed with, in order to avoid overheating of the contents. Steam from a boiler, not shown in the sketch, is passed through the pipe V, and is raised to a temperature of over 260° C.

FIG. 21.



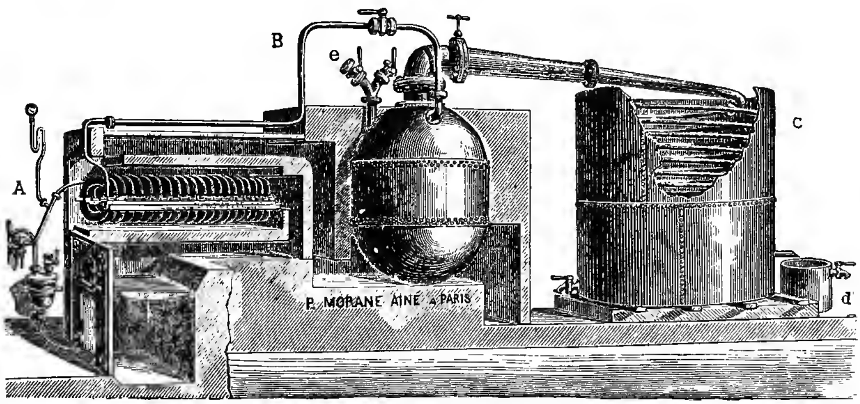
Apparatus for the Distillation of Fatty Acids.

(500° F.) by being made to circulate through several coils of iron pipe, heated by the furnace A. The superheated steam enters the still through a pipe, which terminates in a coil at the bottom of the vessel, and is perforated, so that the steam may be uniformly distributed through the fatty acids, and the regularity of their distillation maintained. When the temperature of the fatty acids has been raised to the desired point by the steam and the fire, the latter is allowed to die out, and the distillation carried on by the superheated steam alone. The temperature of the fatty acid vapour, as it leaves the still, varies, but 271° C. (520° F.) may be mentioned as a suitable temperature for obtaining a rapid distillation, and a distillate of good colour. The steam and fatty acid vapour leave the still by the alembic F, and are condensed, as they pass through the upright pipes C. These pipes are made of copper, and may be jacketed, a current of cold water from O, which circulates round them, causing the condensation of the vapours. The flow of water must be regulated so that, as it leaves the condensers at S, its temperature is sufficiently high to prevent the fatty acids from solidifying.

In some cases the condensation of the bulk of fatty acids is effected by air cooling only; the number of pipes then requires to be increased, the last one or two being jacketed, and cooled by water, for the condensation of the more volatile portions of the distillate. The mixture of fatty acids and part of the water collects in the bends of the condensing pipes C, and is received in the vessels D.

At the beginning and towards the end of the distillation, the fatty acids are somewhat dark in colour; these fractions are put aside for redistillation. It is impossible to effect the distillation of the whole of the contents of the still, some neutral fat, resulting from the incomplete saponification of the raw fat, remaining behind, together with a quantity of tarry matter, as a decomposition product. When the still has cooled down somewhat, this residue is blown out through a pipe, reaching to the bottom of the vessel, to another still, made of cast iron, in which, by distillation at a higher temperature, a further instalment of fatty acids is obtained. The residue in the still, after cooling, appears generally as a bright, black, brittle mass, known as "stearine pitch,"

FIG. 22.



Apparatus for the Distillation of Fatty Acids.

employed for the making of carriage varnish and for other purposes. The residue from the distillation of the bulk of the fatty acids, instead of being distilled to pitch, may be treated with sulphuric acid, the glycerin recovered, and the fatty acids distilled; or it may be re-saponified.

In order to economise fuel and labour, fatty acids are sometimes distilled continuously—that is, the fatty acids are fed into the still while the distillation is progressing, and the residue removed after a quantity of fatty acids, corresponding to perhaps three or four charges by the ordinary process, has passed through the still.

When fatty acids which have not been properly acidified are distilled, a quantity of acrolein, which is soon recognised by its effect on the eyes, and of liquid and gaseous hydrocarbons is formed; the latter are said to result from the decomposition of part of the fatty acids, if the temperature has been high. J. Bouis attributes their formation to the decomposition of the tarry matter, taking place at the end of the distillation. MM. Cahours and Demarçay have made an examination of the liquid products, and have obtained from them a series of solids, almost identical in composition with the hydrocarbons present in American petroleum.

Fig. 22 shows a simple form of still and condenser, constructed by P. Morâne.

Steam enters the superheaters at A, and then passes to the still by the pipe B. The fatty acid vapour and steam are condensed by causing them to pass through the worm C, kept comparatively cold by a current of water circulating through the outer vessel, and the products collected in the vessel d. The residue from the distillation is blown out through the pipe e.

A. Michel * has devised a still intended to be used in conjunction with his autoclave, already described, but it may be used for the distillation of fatty acids obtained in other ways.

The general construction of the vessel and its condenser is much the same as that of the apparatus represented by Fig. 22. The still itself, however, is more elliptical in form, and thus gives a larger superficial area of evaporation. The products are condensed by passing through a cooled worm; at the end of this worm a continuous action pump is connected, which serves to draw off the vapours. It is claimed that, in this way, the time required for the operation is reduced, and that the temperature of the distillation is diminished considerably, a larger proportion of fatty acids of good colour being produced.

L. Hugues' Apparatus is composed of two stills, placed side by side, in the same furnace, and so arranged that they may be heated alternately; when the first charge is distilling, the temperature of the contents of the second still is raised by the waste heat. The alembics from the two stills unite in a wide, upright pipe, into which a current of water is injected, which causes the instantaneous condensation of the fatty acid vapour. Economy of fuel and rapidity of distillation are the principal points claimed for this form of apparatus.

Julien and Blumski's Apparatus † (better known, perhaps, under the name of P. Marix) consists of a horizontal boiler, with two outlets connected with separate condensers. The steam is made to traverse the material backwards and forwards, through a series of pipes, the ends of which project through the sides of the boiler, and are heated in a furnace underneath the end of the still. The steam raises the fatty acids to its own temperature, and is distributed through the material by passing through two perforated worms extending throughout the whole length of the still. The vapours are condensed by passing through two cooled worms, and the fatty acids afterwards separated from the water. This apparatus is worked at a low temperature, and the distillation is necessarily slow.

THE CRYSTALLISATION AND PRESSING OF FATTY ACIDS.

The fatty acids obtained by the various processes described, consist of a mixture of the solid acids, palmitic and stearic, and the liquid acid, oleic. The setting point of the mixture ranges from about 40° to 44° C. (104° to 112° F.), according to the class of raw fat employed, the colour of the mixture being more or less brown. In order to raise the setting point and improve the colour, the oleic acid must be removed; this is accomplished by cold and hot pressing. Many of those candles known as "composites" are made from distilled fatty acids direct, without removal of the oleic acid, but they are greasy to the touch, and generally inferior in their burning.

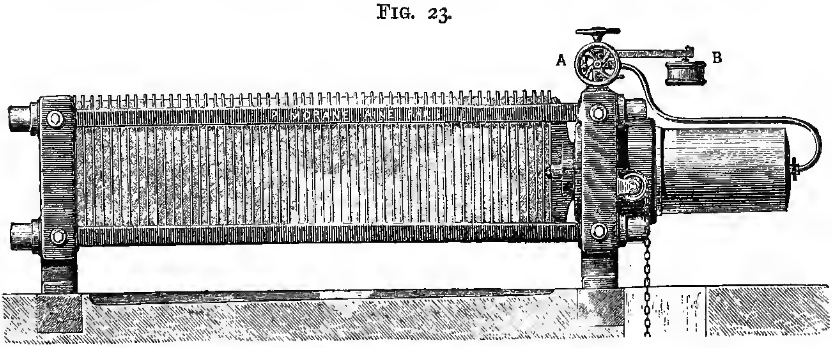
The stearine resulting from the pressing of fatty acids obtained from tallow by the processes of lime saponification or aqueous decomposition is commercially known as "saponified," and commands a higher price than the stearine known as "distilled," obtained generally from a mixture of palm

* Eng. Patent, No. 8403, 1885. † Eng. Patent, No. 14,700, 1884.

oil and tallow, by pressing the distilled fatty acids. Before they are pressed, the fatty acids are first boiled by means of free steam, in a large wooden vat, with water containing a little sulphuric acid. After settling, the acid water is run off through a tap at the bottom of the vat, and the fatty acids again boiled, this time with pure water. The water is run off and the fatty acids transferred to shallow, tinned-iron pans, in which they are allowed to crystallise. These pans are supported in large iron racks, sufficient space being left between each pan to allow free access of air, in order to promote the cooling of the fatty acids.

The filling of the pans may be done by hand, but the labour involved in this is often reduced by allowing the fatty acids to flow from a reservoir or through a pipe, above each rack, into the pans, which are so made and placed that when those at the top of the rack have been filled the fatty acids overflow them and fill those underneath. The fatty acids are then allowed to remain in the tins, for crystallisation, from twelve to twenty-four hours, according to the season. Good crystallisation is the most important point to be attended to, in order to obtain successful pressing. Each manufacturer

FIG. 23.



Hydraulic Press for the Cold Pressing of Fatty Acids.

has his own method of causing the fatty acids to assume that crystalline form which allows the oleic acid to be most readily removed. The object is generally attained by mixing, after saponification, the fatty acids obtained separately from different fats. Palm and tallow acids, in the proportion of 60 per cent. of the former to 40 per cent. of the latter, yield a mixture well suited for pressing.

The oleic acid might be removed in one operation by hot pressing, but a considerable quantity of the solid acids would be unavoidably extracted at the same time. It is therefore generally considered advisable to press the fatty acids first cold, and thus remove the bulk of the oleic acid, and, by exposing the pressed cake to hot pressure, complete the removal of the remainder.

Cold Pressing.—For cold pressing, some manufacturers employ vertical presses; others prefer the horizontal form. Fig. 23 represents a horizontal press constructed by P. Morâne.

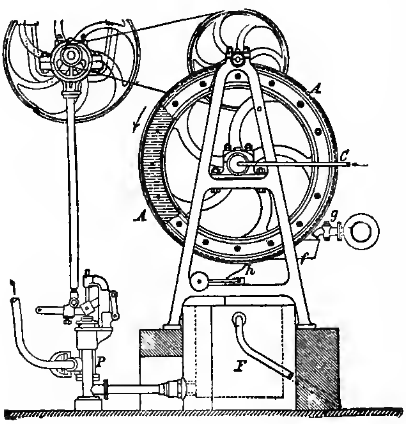
The crystallised cakes of fatty acids are transferred from the tins to strong, woollen bags, adjusted to the size of the cakes, and the bags placed in the press alternately with thin iron plates. When the press has been charged, the stopcock A, which regulates the supply of water to the cylinder, is opened, and the pressure applied, at first gradually, so that it may be equally distributed over each part of the cake, and then more strongly, until

the oleic acid has been removed as far as possible. The valve B serves to prevent the pressure from becoming excessive. The oleic acid flows from the plates into a trough underneath the press, and, as it runs from there, is collected in suitable vessels. The pressure is then relieved and the pressed cakes withdrawn.

The cold pressing generally removes, in the case of fatty acids obtained by saponification, about 45 per cent. of the weight of the acids, about 10 per cent. of oleic acid remaining to be extracted by hot pressing. Fatty acids, which have been acidified and distilled, yield a much smaller quantity.

The solid fatty acids contained in the expressed oil may be recovered by filtration or pressing, after exposure of the mixture to an atmosphere cooled by a freezing machine, the oleic acid obtained being less liable to deposit solid acids in cold weather. Some special forms of apparatus have been lately devised for causing the cooling of the expressed oil. Fig. 24 represents one of these, designed by Petit Brothers, which is in use in certain factories. It consists of a hollow cylinder A, which is made to revolve by mechanical means, and is kept constantly cold by causing ice-cold water to circulate through it from the pipe C. The oleic acid to be treated flows through the pipe *g*, into a shallow vessel *f*, which is so placed that the cylinder dips into its contents, and carries them upwards upon its sides as it revolves. The oleic acid is thus cooled, and the magma of solid and liquid acids is removed from the cylinder by the scraper *h*, falling into the vessel F, which is jacketed, the mixture being thereby prevented from becoming warmer. The cold water, as it leaves the cylinder, passes round the vessel F. The mixture of solid and liquid acids is then separated by being passed through a filter-press by means of the pump P. The finished oleic acid is commercially known as "oleine," and is used for the making of soap and for the oiling of wool. The solid acids are then removed from the filter-cloths, and may be mixed with the bulk of the acids obtained by the cold pressing.

FIG. 24.



Apparatus for the Cooling of Oleic Acid.

Hot Pressing.—The cakes of fatty acids obtained from the cold pressing, still contained in the press-bags, are placed between the heated plates of the press, the sides of these plates being covered with "bands" of matting made of horse-hair. These cakes, before being hot-pressed, are sometimes melted up, and re-crystallised. Horizontal presses are employed, Fig. 25 representing their general form. Steam from the pipes A A′ is distributed through the series of iron pipes *b b b*, each of which is connected with one of the press-plates C, which are hollow. These pipes are constructed on the "stuffing-box" principle, so that the plates may be readily moved backwards and forwards in the charging and discharging of the press; they are, however, liable to get out of order, and india-rubber tubes are frequently substituted for them. From twenty to thirty cakes of fatty acids may be pressed in one operation. When the press has been charged, the steam is passed through the plates, and when they have become heated to a temperature of about 60° to 65° C. (140° to 150° F.), the pressure is applied by opening the stopcock *d*, and is controlled by the valve *e*. The pressing of a charge, including the

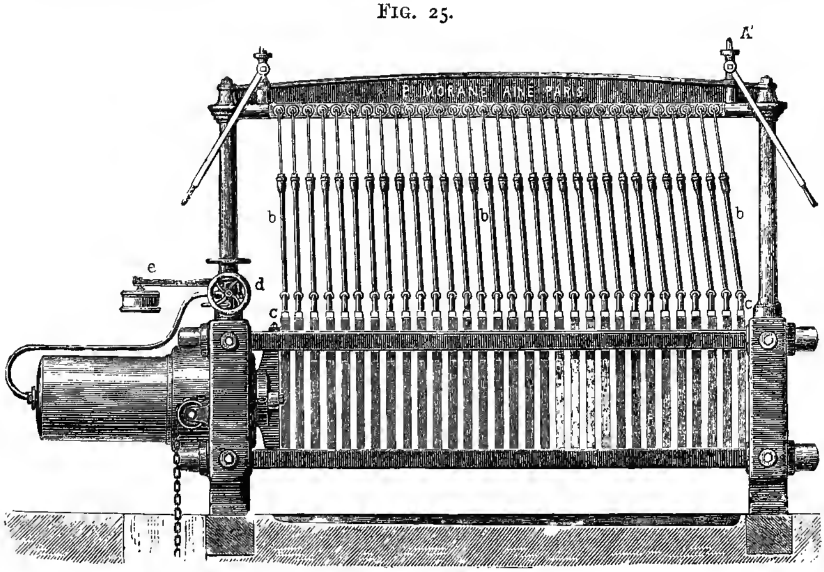
time required for the charging and discharging of the press, generally takes from a half to one hour.

Successful pressing requires a considerable amount of care as regards the regulation of the pressure and the temperature at which it is applied. When the operation has been completed, the pressure is relieved, the bags and their contents removed from the press, and the cakes of stearine withdrawn.

The expressed mixture of oleic acid and solid acids collects in a shallow iron tray underneath the press. The solid acids are recovered from this mixture by cold pressing; or their recovery may be effected indirectly by adding the mixture to the melted fatty acids, before crystallisation, at the beginning of the process of pressing, the addition of the mixture at the same time assisting to produce the suitable form of crystal for good pressing.

The cakes of hot-pressed stearine, as they are discharged from the press,

FIG. 25.



Hydraulic Press for the Hot Pressing of Fatty Acids.

are examined, and those parts round the sides which, from their colour, still appear to contain some oleic acid, are cut off and put aside, to be crystallised and re-pressed. The bulk of the stearine is then melted up and boiled in a large open vat with water containing a little sulphuric acid, until it appears quite bright. This boiling removes small quantities of oxide of iron, resulting from contact of the stearine with the press-plates, and other impurities with which it may have become contaminated. The acid water is separated, the stearine boiled several times with fresh water, and the water run off, when the stearine remains in a condition ready for being made into candles.

THE CONVERSION OF OLEIC INTO PALMITIC ACID.

As the commercial value of stearine is always considerably higher than that of oleic acid or "oleine," it has long been the aim of manufacturers to discover some means whereby the less valuable product might be converted into the more valuable one.

It has been known for many years that nitrous acid, when added to oleic acid, produces solid elaïdic acid. This acid, however, has a tendency to assume its original liquid form, and the reaction has never been successfully employed on a manufacturing scale.

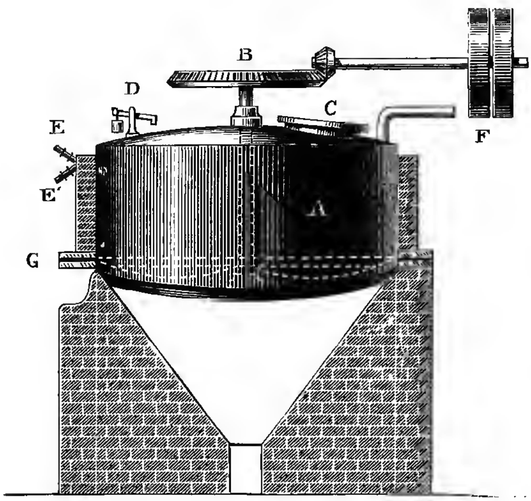
In 1841, Varrentrapp discovered that oleic acid, when heated with a large excess of caustic potash, is decomposed, with formation of palmitic acid, acetic acid, and hydrogen, the acids combining with the alkali, and the hydrogen escaping, according to the equation:

$$C_{18}H_{34}O_2 + 2KHO = C_{16}H_{31}KO_2 + C_2H_3KO_2 + H_2.$$

M. Radisson has succeeded in carrying out this reaction industrially, and his process is said to be in operation in certain factories.*

The operation is conducted in a cylindrical vessel A, Fig. 26, called a "cartouche," the bottom of which is made of cast iron and the sides of wrought iron. It is placed upon brickwork, and is heated by a fire, which

FIG. 26.



Apparatus for the Conversion of Oleic into Palmitic Acid.

should be about five or six feet from the bottom of the vessel, so that the contents may be uniformly heated.

From 15 to 30 cwts. of oleic acid (according to the size of the vessel), may be treated in one operation; the charge consisting of 1 part of oleic acid to 1.67 parts of caustic potash lye, of 1.40 sp. gr. When the charge has been introduced, the agitator B is set in motion, heat is applied, and the steam allowed to escape by the man-hole C. When the "soap" is dry, the man-hole is closed; the liberated gases then leave the apparatus by the pipe F, and pass through a tower-condenser to a gas-holder.

From 300° to 310° C. (572° to 590° F.) is the most suitable temperature for the reaction, and at 320° C. (608° F.), when destructive distillation threatens, steam and water are injected into the mass through the pipes E and E′.

After from thirty-six to forty hours, including the time required for charging, the operation is complete. The outlet-pipe at G is then opened, and the palmitate of potassium allowed to fall into an open tank, in which

* See "Soap, Candles, Lubricants, and Glycerin," Lant Carpenter, p. 266: Journ. Soc. Chem. Ind., vol. ii. p. 98.

it is boiled with water by means of free steam. When allowed to settle, a separation of the contents of the tank takes place, the upper layer consisting of a solution of palmitate of potassium, and the lower layer of potash lye. The palmitate of potassium is then decomposed in a separate vessel by sulphuric acid, and the palmitic acid washed with water. It is said to have a setting-point of from 50° to 52.8° C. (122° to 127° F.), and may be purified by distillation, when it yields a material of good colour, well suited for candles when mixed with ordinary stearine.

The potash-lye is causticised in the cold by agitation with lime, the carbonate of lime removed, and the lye evaporated to the required strength. On standing, it deposits small quantities of carbonate and sulphate of potash, whilst crystals of acetate of potash form upon the vertical parts of the tank. The potash-lye is employed for the treatment of another quantity of oleic acid, and the crystals of acetate of potash, separated from the lye by a centrifugal machine, are decomposed in a special still, with sulphuric acid, and the acetic acid recovered and purified. The sulphate of potash resulting from the decomposition of the palmitate of potassium is most economically regenerated by the Leblanc process.

The yield of palmitic acid depends on the nature of the fatty substance from which the oleic acid was derived. Oleic acid from tallow, saponified by lime, is said to yield 91 per cent. of palmitic acid, fit for candle-making, whilst oleic acid which has been distilled yields 87 per cent.

The cost involved in the preparation of white palmitic acid is estimated at £13 per ton; but may be reduced to about £7 10*s*. per ton if caustic soda be substituted for potash. When caustic soda is used, a quantity of paraffin requires to be added, in order to equalise the temperature of the mass of difficultly fusible oleate of soda.

PROPERTIES OF STEARINE.

Industrially prepared stearine is a white, more or less hard, solid, possessing a faint characteristic odour, which should be free from all "salviness." It should not feel greasy to the touch. It is easily soluble in alcohol, ether, and light petroleum, separating from the hot solutions, on cooling, in small crystals.

The setting point of "saponified" stearine ranges from about 52.2° to 55.5° C. (126° to 132° F.), and that of "distilled" from about 47.8° to 52.2° C. (118° to 126° F.). It may be determined by the method described under "Raw Materials."

To be suitable for candles, stearine, when melted and allowed to cool slowly, should exhibit a "close-grained" crystal, otherwise candles made from it will present an appearance of "seeding," and on being broken will not give that characteristic "snap" which distinguishes well-made stearine; this result is generally obtained by mixing stearine from different fats in the requisite proportions for giving a suitable crystal, or by working on a mixture of fatty acids from different fats made in the properly adjusted proportions. Stearine should be quite free from salts of all kinds, and leave no ash on ignition.

SECTION III.

CANDLE MANUFACTURE.

BY

L. FIELD AND F. A. FIELD.

THE invention of candles may be regarded as contemporaneous with the need of artificial, portable means of lighting. We may define a candle as a porous, combustible core, surrounded or merely saturated with a fusible, inflammable solid. Accepting this definition, the man who first selected a more than ordinarily resinous brand to serve as a torch to lighten up the darkness, was the primeval chandler. This is not merely conjecture. For at the Colonial and Indian Exhibition of 1886, where the resources and appliances of the most aboriginal races were displayed, devices for obtaining a continuous light might be seen almost rivalling in simplicity that instanced above. Thus, one toiler on the West Coast of Africa burnt oily nuts in clay saucers; another, more ingenious, strung these nuts on a twig, thus ensuring a continuous illumination.

Wherever Nature had furnished fuel, whether liquid or solid, grease, wax, or oil—animal, vegetal, or mineral—the natives had taken advantage of it according to their lights, and employed it in some form or other for lamps or candles. One drew a wick through the body of a penguin, so fat that it exuded sufficient oil to maintain a light for hours; another had filled a conch-shell with oil, and inserted a mass of some fibre for wick; whilst a third showed a rush coated with the hard wax of the *Myrica cerifera.*

Saving the material, which was hard and bad to burn, the last-mentioned candle differs in no way from the rushlight that a thousand years and more ago was instanced by Apuleius in the "Golden Ass" (Metam. iv.), where servants come with "tardis, lucernis, *sebaceis* et cereis"—pine torches, lamps, *tallow* and wax candles. These candles were, doubtless, what we term dips; and were made then precisely as in our days, namely, by dipping rush-piths (*scirpus*) into melted tallow. Wax candles were made in the same way, substituting the harder and finer material.

We find frequent reference to candles in the later classics, although, as art advanced, the lamp gained in prestige, as affording more scope for ornament. That candles, in Martial's time, were not considered so "fashionable" as lamps may be gathered from his Apoph. 42:

"Hic tibi nocturnos praestabit cereus igneo
Subducta est puero namque lucerna tuo."

"The footman, I am sorry to say, has walked off with your lamp, so you'll have to put up with a candle."

Subjoined is an attempt to give the progressive stages of the development of the candle in a chronological sequence. But it must be borne in

mind that these stages overlap each other considerably, and that at no period can one form be said to have died out, or another sprung into existence. The link still flares in processions, the rushlight in its cage still renders darkness visible in far country places, and even in London; the miner persists in his preference for the tallow dip, the cobbler has his "flat candle," and in the south of England a rush, just coated with kitchen fat, and held in an upright prong, lights the bucolic at his evening meal.

Chronological Table of the various Stages in the Development of the Candle.

1. *Torches*, primeval.—Originally resinous pine-boughs, subsequently splints of the same (*taeda*), bound together at intervals, possibly with a core of tow or flax saturated with resin, &c. The word "torch" is derived from the Latin *tortitium*, a twisted thing, a rope, which would apply more properly to the

2. *Link* (*lychnus*, Lat.), which Virgil calls *funalium* (Æneid. ii.):

> "—— dependent *lychni* laquearibus aureis
> Incensi, et noctem flammis *funalia* vincunt."

Here *funis* is evidently a rope saturated with pitch (probably bitumen found in the neighbourhood), which corresponds precisely with our present link, still used in foggy weather and in torchlight processions.

3. *Flambeaux* were a more elaborate and costly form of illuminant, a kind of hybrid between the link and the candle. They consisted of alternate layers of tarry resinous oakum and crude beeswax, with an external coating of white wax. In the seventeenth and eighteenth centuries these were employed to illumine the halls and yards of the nobility, and were carried by the running footmen to light them home in their sedan-chairs. Extinguishers for putting out these lights may still be seen at the doorways of old London mansions.

4. *Dip Candles*: Wax and Tallow *Dips*.—The word candle is derived from the Latin *candela* (Martial, Ep. xiv. 43), from *candeo*, to shine (Sans. KAN). As before said, the use of candles—that is, thin wicks of pith or flax surrounded with wax or tallow—dates from a very early period; although their employment as a means of lighting would not appear to have become general till the commencement of the seventeenth century, before which time oil was the common illuminant.* Wax candles, however, must have been made, as now, in large quantities for church purposes. Venice would appear to have been the home of this industry, which was introduced into Paris in the seventeenth century. But the Wax Chandlers' Company was incorporated in 1484; proof that this manufacture was already an important one.

5. *Mould candles* are said to have been introduced by the Sieur de Brez, in the fifteenth century. Wax does not lend itself to moulding, hence the process was applied to tallow alone. As only the hardest and finest fat could be moulded, these candles were considerably dearer than the dips, and their use confined to the better classes.

6. *Spermaceti candles* appear to have been first made, in England at least, towards the middle of last century, although the solid was employed long before as a basis of ointments. One Sarah Field describes herself on a bill-head, 1756, as a "Maker of the new Sperma Ceti Candles."

* In the household expenditure of the Earl of Lancaster (1313), we find "2319 lbs. of tallow candles, and 1870 of lights for Paris candles, called perchers" (probably wax).—"Food Journal," March 1, 1871.

7. Cambacères introduced plaited wicks about 1820. Till that period, twisted cotton yarn was the only core available.

8. Chevreul discovered stearic acid, 1814–15; and Milly manufactured stearine candles (Bougies de l'Étoile), 1832.

9. G. F. Wilson brings out composite candles of cocoa-nut stearine and distilled palm oil (palmitic and stearic acids).

10. Night lights (mortars) introduced.

11. Paraffin manufactured by James Young (Pat. 1850). Paraffin candles manufactured at Lambeth by J. K. Field (Pat. 1854).

12. Ozokerit distilled and candles manufactured therefrom (F. Field and G. Siemssen, Pat. 1870).

The above may be regarded as a fair summary of candle-lore. For much interesting information on this branch of the subject, the reader is referred to "The Old Days of Price's Patent Candle Company," by G. F. Wilson, F.R.S.; "Solid and Liquid Illuminating Agents," Cantor Lectures, Society of Arts; and Beckers' "Charicles," and "Gallus."

The composition and manufacture of modern candles next claims attention. There are five distinct classes of candles now made: tallow, wax, spermaceti, stearine (including composites), and paraffin (including ozokerit). The importance of these is in inverse ratio to their age; paraffin, the last, preponderating enormously over the others, and tallow is almost extinct as a candle material, *per se;* though, as the source of stearic acid, it is of great value. As the nature and preparation of these materials have been treated of in another part of this work (Fats and Oils), they must be considered here as ready for immediate use. Before proceeding, however, to discuss the various processes, a few words on the wick are necessary.

The Wick.

Until the introduction of plaited wicks (about 1820) the same twisted cotton core was used for all kinds of candles as is still employed in tallow-dips and moulds. This bulky structure, having no determining impulse to one side or the other, remained in the centre of the flame, occluded from the air. Hence the light soon grew dim, owing to the absorption of the heat by the mass of carbon and mineral matter. To maintain the wick at a proper height, snuffers were necessary, and many and complicated were the expedients devised for removing the objectionable "snuff," without allowing the nauseous vapours of acrolein, &c., to escape into the air. Over fifty patents have been taken out in this line alone, some of which are marvels of mechanical ingenuity. But a simple, though beautiful, scientific expedient rendered all these appliances abortive. In 1852, Mr. William Palmer patented his "Metallic Wick," into which a thread is introduced, saturated with nitrate of bismuth, and coated with finely powdered metallic bismuth. As the flame reaches the wick, the metal is fused into a tiny globule, which by its weight forces the fibre into a curve, thus bringing the extremity into contact with the air. The carbon is oxidized to carbon dioxide, and the bismuth volatilised. Tallow candles with wicks thus prepared were especially employed in spring-lamps (for carriages, &c.), and the sale was very large.

Another expedient for overcoming the straightness of the wick was, and is still, employed by Messrs. Ogleby & Co. in the manufacture of their composite candles. Here the wick is wound tightly round a cylinder of iron, and brushed with a thin size. As only one side of the wick is stiffened, a strong tendency to curl is imparted, and the necessity for snuffing removed.

But the class of candle for which these wicks are required is almost obsolete, and plaited wicks have taken the place of twisted. It must not be imagined, nevertheless, that with the introduction of plaiting any further

improvement in this portion of the candle became unnecessary. On the contrary, the wick may be considered as the soul of the candle; for, on the proportion, preparation, and condition of this slender core the candle depends for the proper discharge of its functions.

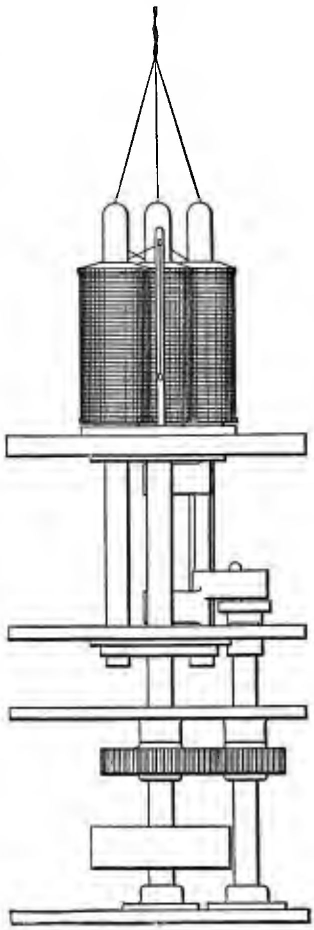
A candle-flame is a gaseous cone, in which there are three district layers or zones of chemical action. The first, or inner, immediately surrounding the wick, is non-luminous, and consists of the candle material, sucked up by the wick, and vaporised at the point of contact with the flame. In the second, the luminous cone, the vapours become partly decomposed, free carbon and dense hydrocarbons being formed. In the third cone, total combustion takes place, and carbon dioxide and water are produced.

Now it is evident that the luminosity of the flame depends on the adjustment of supply to demand; in other words, on the amount of material vaporised being not in excess of the heat disposable for its combustion. Where this condition is not fulfilled—that is, when the wick is too large or too porous, and supplies the liquid fuel too rapidly—an over-draught of heat for vaporisation ensues, and imperfect combustion is the result, shown by a dim light and evolution of unconsumed carbon as smoke.

On the other hand, where the wick is too small, the pores of the cotton become clogged, the material is melted faster than it can be vaporised, and the wick is "drowned," until relieved by the molten mass breaking down the walls of the cup, and escaping down the side of the candle, a phenomenon technically termed "guttering." Both phenomena are equally objectionable, and have to be guarded against by careful adaptation of the wick, in dimension and preparation, to the size and substance of the candle.

Great care is taken in the manufacture of wicks. The cotton is specially selected, with particular reference to the absence of lumps, knots, or other irregularities and impurities. It is then plaited by special machines, of which the subjoined cut, Fig. 27, will give a good idea.

FIG. 27.



Wick-plaiting machine.

Plaiting Machine.

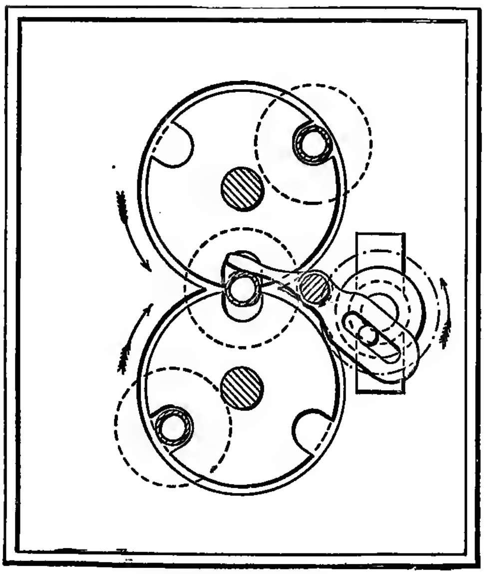
The bobbins are held in the notches shown in Fig. 28, on the discs, which rotate at an equal speed, but in opposite directions Each bobbin spindle as it passes between the axes of the discs is transferred from the discs on one axis to those on the other, the bobbins being thus made to describe a path resembling the figure 8. This transfer is controlled by a switch which crosses from side to side in the intervals between the passages of the bobbins, so as to pass the bobbins to the right and left alternately. A crank-pin, shown in Fig. 28, moves the switch automatically at the proper

intervals, and so ensures uniformity in the plait of the cotton, in an almost noiseless machine, when compared with other designs.

In order to prepare the wicks for the proper discharge of their duties in the candle, they are soaked in weak solutions of certain chemicals. The object of this is, primarily, to supply "backbone" to the fibre, too weak of itself to resist the up-draught of the flame. An unprepared wick soon "feathers" away, leaving a short stump, which is speedily "drowned" by the melted wax, &c. A little borax or boric acid supplies the necessary substance.

Secondly, where the material is readily fusible as in paraffin, the pores of the wick must be slightly obstructed with some material which can be relied upon to decompose or volatilise when its work is done. Numerous salts—generally of ammonia and potash—fulfil these requirements in varying degrees. Nitrate of ammonia is a very favourite chemical.

Fig. 28.



Wick-plaiting Machine.

Thirdly, where the material is difficult of fusion, and the supply of fuel limited, the capillary tubes must be freed as much as possible from obstructive mineral matters. This is effected in various ways, with dilute acids, &c.; but great care has to be exercised, lest the wick grow too weak, or retain a tendency to knot, and break in the candle machine.

Some of the usual constituents of these "pickles" for wicks are: a solution of either boric acid, nitrate of soda or potash, chloride of ammonium, &c., each having its advocates; but a solution of boric acid with a few drops of sulphuric acid is now conceded to be the most effective.*

In one or other of these the wicks are soaked for some hours. The hanks are then placed in a centrifugal machine, by the rapid rotation of which the bulk of the solution is expelled, without subjecting the fibre to any torsion or other strain.

The hanks are next hung up in a warm air current to dry thoroughly, and are then, for machine-made candles, transferred to spools; the greatest care being employed to detect and cut out the least knot or roughness.

We can now proceed to consider the several methods by which the wick is coated with the material. The methods now in vogue for performing this operation are: Dipping, Drawing, Pouring, and Casting.

Dipping is employed in the manufacture of tallow and inferior composite candles only. As the introduction of cheap paraffin lights has nearly ousted these grades, it will not be necessary to dilate much on a process now nearly obsolete.

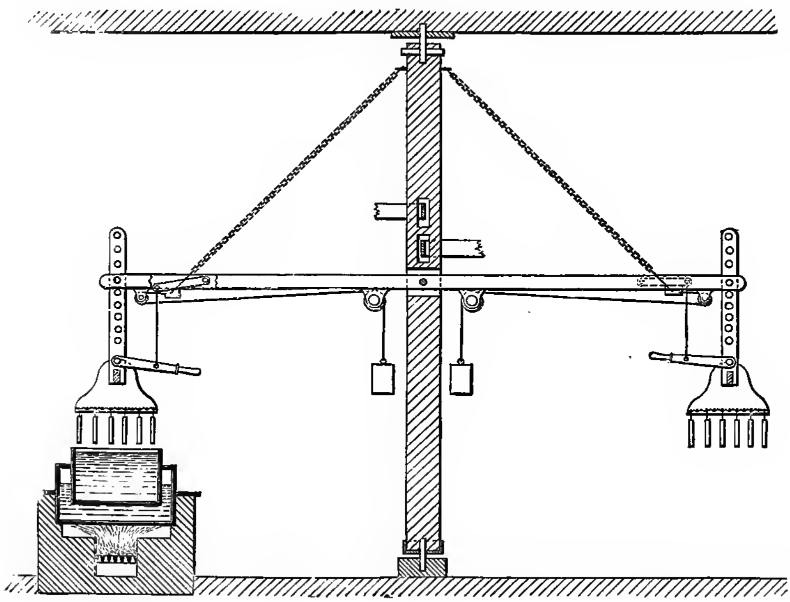
Rushlights, the earliest form of dip candles, were made formerly in

* See Christiani, "A Technical Treatise on Soap and Candles," p. 489, l. 26, &c.

almost every country household. Kitchen grease supplied the combustible; a rush-girt brook the wick. All refuse fat was carefully preserved for the melting day, when it was boiled with water and a little salt, which "rendered" or purified it from extraneous matters.

The clean fat was then skimmed off and transferred to a pan, where it cooled to the consistency requisite to cause it to adhere to the wick. This consisted of a rush, deprived of its bark but for one thin strip, to give it support. Four such piths were joined together at one end, and held in the hand so that each passed between two fingers. They were then immersed in the fat for some time, withdrawn, and when the first coat had hardened sufficiently, dipped again, repeating the operation until they had acquired

Fig. 29.



The Edinburgh Star Dipping Machine.

the desired bulk. These rude candles, as may be supposed, burnt very badly, with a feeble light. They required no snuffing, however, and thus could be employed as nightlights, for which purpose they were imprisoned in huge cages of gauze, or perforated tin, and placed on the hearth.

The regular *Tallow-dip* of commerce was made much in the same way, with the substitution of cotton yarn for rush-pith. Of course, in factories more elaborate appliances for holding and dipping the wicks were necessary, and numerous; but a brief description of the latest form will suffice, as it embodies all the principles of its predecessors, and is in actual use.

Dipping Machine.

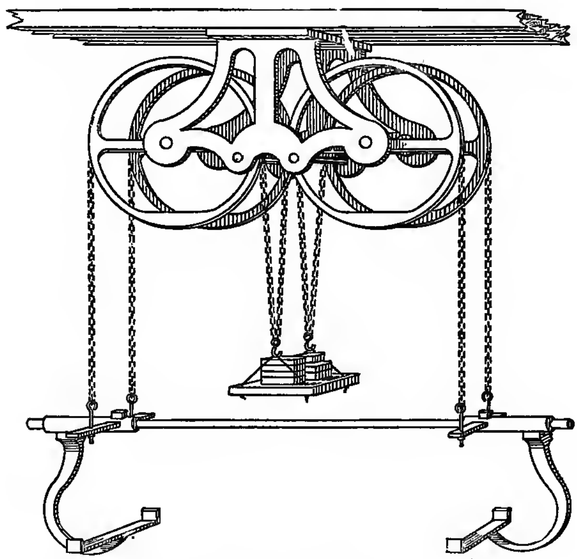
This machine, Fig. 29, known as the "Edinburgh Star," consists of a vertically revolving shaft, having three or more horizontal arms, which extend right through the shaft, and are pivoted centrally therein. From the extremities of these arms are suspended the bars holding the wicks to be dipped, and these come over the vat of melted grease in succession as the shaft

revolves. By pulling the lever on the frame containing the wicks, the counter-lever on the arm is drawn down, thus slackening the chain which supports it, so enabling the wicks to be dipped. On releasing the lever, the former tightness of the chain is restored by means of the weights, which pulls the sliding wedge holding the chain into its normal position.

Fig. 30 shows a system of balanced weights and pulleys, employed in the Dipping Machine of Price's Patent Candle Co., the weights on which may be varied to suit the increasing weight of the candles in course of dipping, the bar or plate on which these are suspended resting on the brackets shown in the illustration.

The material employed for this purpose (cheap composite candles) is a distillate of palm oil. These candles are generally finished off by dipping them in stearine of a higher melting point and better colour.

FIG. 30.



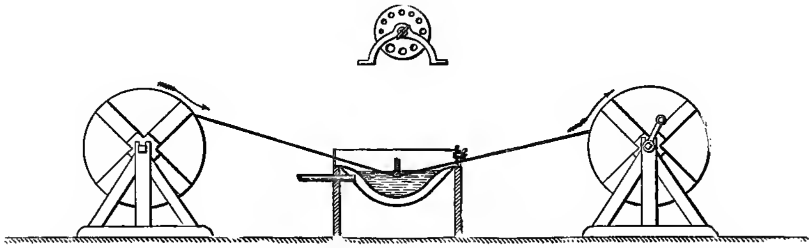
Price's Dipping Machine.

Drawing is confined now practically to the making of "spills" or lighting wick, and the smaller sizes of tapers, for Christmas trees, &c. The wick (cotton yarn) is wound off a drum which revolves on a spindle, on to another drum—generally about thirty feet away—turned by hand. In its passage, the wick traverses a bath of wax or stearine, passing out through a plate, or die, perforated with holes of increasing calibre (from $\frac{1}{16}$ in. to $\frac{1}{2}$ in.)—see Fig. 31. When all is wound off the first drum, the process is reversed, and the wick passed through the hole next in size, and so on, until of the requisite diameter. For lighting wick, this varies from $\frac{1}{12}$ to $\frac{1}{8}$ inch, for tapers from $\frac{1}{6}$ to $\frac{1}{2}$ in. While still soft, the coated wick is removed from the drum, and cut into lengths of from 7 to 22 inches. These are made up into bundles, one end of which is dipped into boiling water, and the wicks sharply "flipped" over the operator's arm. This removes the wax from the tips, and "feathers" them, rendering the process of lighting considerably speedier than with the unprepared ends.

The thicker cables (generally of beeswax) are cut into shorter lengths, from 2 to 5 or 6 inches. A small piece is removed from one end by the simple means of a knife and the hand, and the taper is finished. These

tiny candles vary in weight from 40 to 400 to the pound, and are in enormous demand at Christmas-time. The last coating is generally coloured with some gay pigment—vermilion, ultramarine, &c. Of late years the introduction of paraffin tapers of delicate tints and great transparency, at about one-third the cost, has greatly diminished the consumption of the dearer wax-tapers.

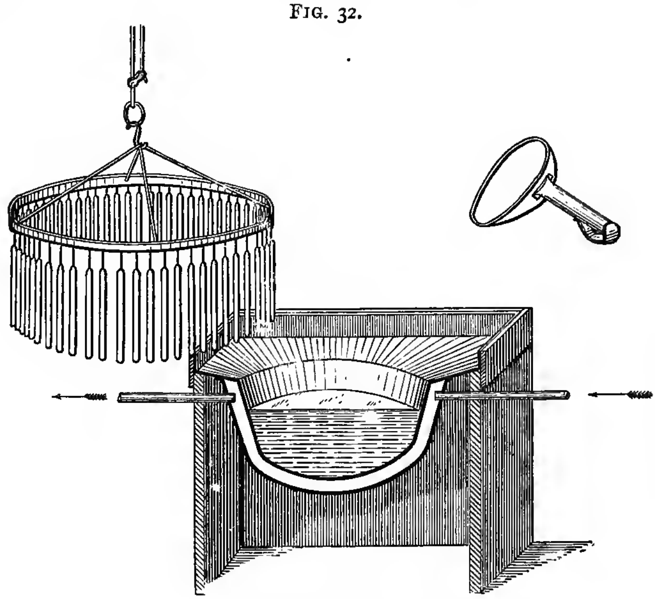
FIG. 31.



Drawing Machine and Die Plate.

Bougies.—Another form of the drawn candles is that known as "bougies." These consist of a length of the coated wick, generally about $\frac{3}{16}$ths of an inch in diameter, so coiled as to be easily unrolled as desired, and much resembling, when made up, the ordinary ball of string. They are employed by users of sealing-wax, and otherwise where the light required is of short duration.

FIG. 32.



Pouring Apparatus.

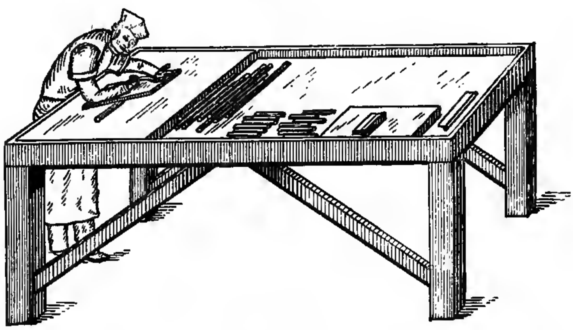
Pouring is restricted entirely to wax candles. Although the use of these is nowadays almost wholly confined to churches, and in a few cases carriage lamps, the output is large enough to warrant a full description of the process of manufacture, which possesses a special interest in that it varies nowise from that practised centuries ago, if we may judge from the old descriptions and drawings.

The apparatus is simple and is well shown in Fig. 32. A hoop, with

strings placed at regular intervals on its circumference and suspended from a hook by three cords terminating in a swivel; a pan with means of heating, and a ladle, make up the wax chandler's inventory. But the art of using these simple tools aright needs a long apprenticeship.

The workman first attaches the lengths of wick to the strings on the hoop, by means of a little wax. Thereupon he suspends the hoop over the pan, filled with melted wax. The temperature of the latter has to be nicely regulated according to the heat of the weather. It should run evenly and

FIG. 33.

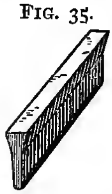


Rolling.

easily over the whole length of the core, yet congeal rapidly enough to receive and retain a second coating when its turn arrives. The operator now gently revolves the hoop and pendent wicks over the pan, pouring the wax over each wick from the ladle, much as a cook bastes a joint. After six or eight coatings, according to the weather, the hoop is removed to cool, and another substituted. To complete an ordinary candle (about six to the pound) about six pourings are sufficient.

FIG. 34.

FIG. 35.



While still soft and warm, the full-sized candles are plucked loose from the strings, and transferred to a smooth marble slab. Here the operator rolls them under a board furnished with a handle, Fig. 34, through which he passes his elbow, leaning all his weight upon the candles while rolling them. This operation, illustrated at Fig. 33, removes the irregularities of surface inseparable from even the most skilful pouring, and imparts a polish. After this, the cylinders of wax are cut down to their proper lengths, and "tipped" by means of a sharp-edged piece of wood, Fig. 35, an operation requiring much skill and practice. The candles are now complete. A skilful workman will calculate the weight of his goods to a nicety, seldom making an error of above $\frac{1}{4}$ oz. in the pound.

For church purposes some gigantic candles of 30 and 40 lbs. weight are made, sometimes exceeding 9 inches in diameter and 7 feet in length. These require extraordinary care, and are afterwards painted and decorated. On the Continent this art is carried to a pitch quite unknown in England, the most exquisite devices in bas-relief and intaglio being applied to candles for Roman Catholic altar decorations.

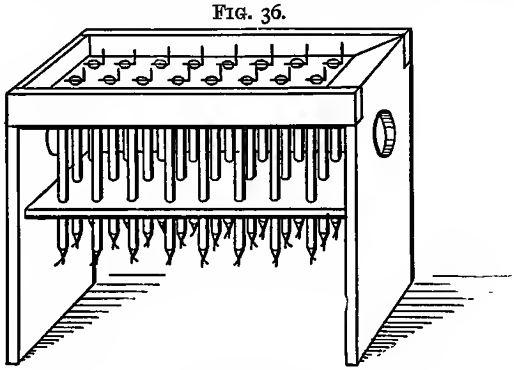
Candles of unbleached beeswax, for funeral purposes, are also sometimes demanded, but their manufacture does not vary from the above. It must be remembered that the "wax" mentioned throughout is pure, air-bleached

beeswax. No other waxes* are of any use, although much has been written about them. Japan, Myrtle, and Carnauba wax burn abominably, and a very small percentage of either will ruin the finest beeswax candle. Some candles, made by the Boers from Myrtle wax found in South Africa, were exhibited in 1886, but they burnt atrociously, and guttered unceasingly.

Mould Candles.

As before mentioned, the Sieur de Brez of Paris is credited with the introduction of this invention into England, if he did not actually pose as the originator of this process of candle-making. Although some 300 years elapsed between the period named (the fifteenth century) and the date when any visible steps were first apparent in the direction of the manufacture of candles by machinery, yet it seems reasonable to suppose that the art of moulding candles must have been carried on from that early time in hand-frames, or sets of moulds, more or less resembling those employed at the present day, since there is a want of information respecting the origin of the "hand-frame" that points to its being a very

Fig. 36.



Hand Frame.

early outcome of the Sieur de Brez's innovation. In the oldest candle factory in London (perhaps in the world), there appears no record of hand-frames being used earlier than 150 years ago, although possibly this may have occurred by reason of that firm's having confined itself almost exclusively to the making of beeswax candles, the first suspicion of hand-frames, as remarked elsewhere, being coincident with the manufacture of spermaceti candles by Sarah Field about the middle of the last century. Be this as it may, we have to accept the hand-frame's history as told, and can only conjecture that the steps between the single mould of the Sieur de Brez and the exceedingly simple piece of apparatus known as the hand-frame of to-day cannot have been very many or of much importance.

Under the description of machine-made candles may also be classed such candles as are moulded in hand-frames, as this will then include all lights turned out of "pipes" or "moulds." The employment of the hand-frame nowadays is restricted to the manufacture of spermaceti candles generally, and of those special sizes or qualities of candles for which there is not sufficient demand to warrant much mechanical assistance in their production.

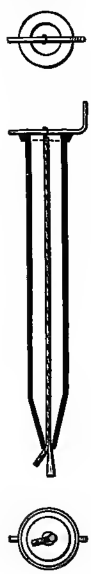
The "hand-frame," as its name implies, is simply a small oblong portable table, or framework of strong wood, carrying a number of pipes or moulds. Its general construction will be readily seen from Fig. 36. It may be

* Except, perhaps, the Chinese Peh-la (Insect-wax), but that hardly ever comes to the English market. It is, besides, so very hard and crystalline as to render the manufacture of candles from it a matter of much difficulty.

of any dimensions within the range of portability, but as a rule would not have a capacity for more than three dozen candles, of a small size, or about half that number of the largest ordinary moulds. Unusually large sizes of candles are made individually in single moulds, the hand-frame never, when charged, being heavier than can be carried by any one of moderate strength. A hand-frame of average proportions measures about 6 inches wide, 24 inches long, and 18 inches deep, and contains three rows each of eight moulds, to produce candles weighing six or eight to the pound.

A single pipe is shown in section in Fig. 37, with a full plan viewed from either end respectively, and the following description of the process of making candles in hand-frames is obviously modifiable when applied to the single pipe.

Fig. 37.



Candle Mould.

The method by which candles are made in a hand-frame is substantially as follows.

The wick for the purpose is previously cut into special lengths to suit the various sizes of candles manufactured in this way, and is technically known as "eyed" wick, having a small cotton loop or "eye" attached to or formed at one end of each length, whereby it can be suspended in the mould. After due preparation, or pickling (as previously described), each length of wick is taken, and the eyed end held beneath the tip of the mould. A piece of fine strong wire, the end of which is fashioned much as a crochet-hook, and having often a wooden handle, is passed through the mould by the operator, who, hooking it into the eye of the wick, then draws this back with it into the pipe. At the trough end of the mould, the hook is removed, and a piece of stout L shaped wire, about 2 inches long, passed horizontally across the mouth of the mould, through the eye, thus holding the wick in a vertical position in the pipe. At the under or tip end, the wick after being drawn straight, but not too tight, is secured in its place by the introduction of a little conical wooden peg, which a light blow with a hammer causes to hold firmly. The illustration of the single mould at Fig. 37 shows the little wire cross-bar, the wick, with its eye, and the securing peg at the tip end. The vertical bend of the cross-bar is of sufficient length to rise above the surplus material in the trough of the frame when this is charged, so as to admit of its being readily withdrawn. Having wicked the whole set of moulds in a hand-frame in this way, the wicks are carefully adjusted by eye to as near the centre of the moulds as possible by shifting the horizontal cross-bars, and with them the wicks, to the required position.

The hand-frame is now ready to be charged. After being filled with the liquid material by means of a "jack," or can with a flat wide spout, the frame is placed in water up to the under side of the trough or in a cool place, according to the requirements of the material or the temperature of the atmosphere, until the candles have set quite hard. The little pegs are then withdrawn from the tips and the horizontal wire bars from the trough end, and the surplus material in the trough is scraped off by means of a blunt knife or "spud" of corresponding width.

The hand-frame is now turned upside down, and a few light blows with a mallet on the moulds speedily and sufficiently loosens the candles to enable them to be drawn out of the pipes. The wicks at the tips are trimmed to the proper length, and the candles are now ready for packing, and the hand-frame for re-wicking.

It may be here mentioned that the chief reason for moulding spermaceti

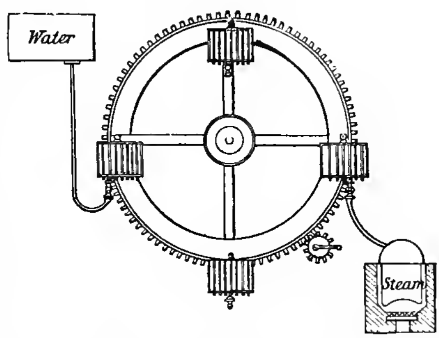
candles in hand-frames is that, having been the first modern candles produced from moulds, the public recognised them by the slight impression across the base left by the little wire bar, and though this material may be equally well moulded in steam-machines, yet the public would be inclined to doubt the identity of spermaceti candles not bearing this little mark.

Moulding Candles by Machinery.

The real inventor of the steam candle-moulding machine is almost as unreal a person as that of the locomotive engine or many another perfected invention of to-day. The mechanism which produces the bulk of our candles is the outcome of successive feats of ingenuity, one improvement following another, step by step, until, from the above described hand-frame, yielding only 4 or 6 lbs. of candles at a time, and that but once every couple of hours, is evolved the continuous-wicking, self-fitting-end making machine, which can give us a couple of dozen pounds of candles per turn-out, two or three times an hour, until the supply of wick is exhausted.

Ever since State protection was granted to inventions, from early in the seventeenth century, the historian, desirous of tracing the progress made in any particular branch of industry, can almost always follow it up by searching the records of the Patent Office Library. Not every man of inventive turn has shielded the work of his brains by a licensed monopoly, but most great inventors have done so, and by this means not only secured to themselves the temporary advantages arising from their inventions, but left a detailed description behind them of their methods, invaluable alike to subsequent workers on the same ground, and to compilers studying the history of their work. Other and less trustworthy sources of information failing us, therefore, in discovering the "inventor" of the candle machine, we can unearth from the Patent Office records a not altogether incomplete history of this apparatus.

FIG. 38.



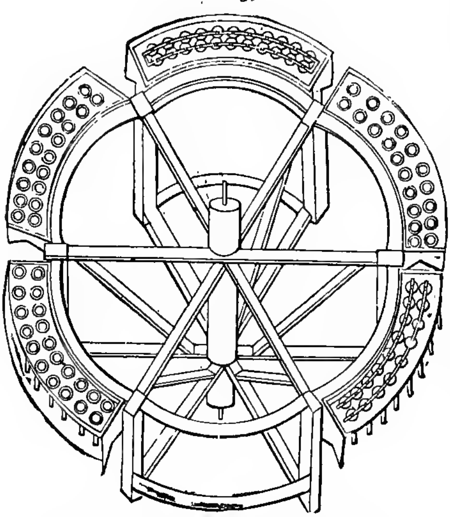
Binns' Candle Moulding Machine.

Binns' Machine.—In the first year of the present century, a Thomas Binns, of Marylebone, invented a candle-moulding machine, the leading idea of which, the alternate application of heat and cold (in the form of steam and water respectively) to the moulds, in an hermetically sealed box, forms one of the chief features in the present make of candle machinery. Otherwise, Binns' apparatus had little else to commend it, when compared with later improvements, although it must be confessed that the introduction of steam and water into the box containing the moulds was of great importance. The drawing at Fig. 38 gives a general view of Binns' machine, which consisted of four such candle frames or boxes of moulds, loosely suspended on the front of the rim of a vertically pivoted wheel, which being arranged to be slowly revolved by gearing, brought the sets of moulds alternately to be connected to the steam or water pipes, according as to whether the moulds were to be heated for the reception of the material or cooled after being

charged with it. A somewhat strange claim of Binns in connection with this apparatus is his asserting its applicability to the manufacture of beeswax candles, which, in effect, lend themselves most reluctantly to machine production. Possibly the wish was father to the thought, that in the contrivance for applying alternate heat and cold to the moulds, the beeswax might show itself readier of extraction therefrom. Be this as it may, even with the machines of to-day beeswax cannot be moulded satisfactorily, and the means and appliances for this branch of the candle-maker's art are the same now as they were 200 years ago or more.

Sampson's Machine.—We have spoken of Binns' candle machine first, because it was the first to show any real advance in the collective manufacture of candles on the then existent hand-frame. But there is one patent prior to that of Binns, bearing the name of Joseph Stacey Sampson, of Moorfields, in Middlesex, and dated 17th June 1796. The idea here divulged is merely the combination of a number of the ordinary hand-frames upon the circumference of a horizontally revolving wheel which brings the troughs serially beneath a vat containing the melted material for charging them. This apparatus will be seen at Fig. 39, which, however, does not show the vat, but only the outline construction of the machine. Sampson's machine, in addition, had a spool of cotton wick, conveniently fixed on the vertical axis of the wheel (also unseen in the figure), so that he could take a length of wick therefrom and thread it through one whole set of moulds (or even the entire machine) by means of little hooks, such as are described in wicking hand-frames, the central position of the wick being maintained by bars of metal the length of the trough, resting over the mouths of the moulds, in which were drilled small holes, centrally over the moulds, to admit the passage of the wick at that end, whilst the tip-end had a similar-sized hole, as in the mould now employed. Sampson's patent covers also a number of small appliances incidental to this particular machine, but otherwise it is not remarkable as an invention, excepting in that it discloses a concentration of various parts, which often forms an important factor in the progress towards perfection of any machine.

FIG. 39.



Sampson's Candle-Moulding Machine.

Palmers' first Machine.—Both candle manufacturers and the public appear to have remained satisfied with the result of Binns' invention for about a third of a century, as genius did not betray itself again at the Patent Office in this direction until the year 1832. At this date William Palmer protected his idea, in spite of Binns' patent of 1801, of encasing the moulds of a hand-frame in a water-tight box, to contain "the water, or other refrigerating liquid," for cooling the moulds. There is really less novelty in this later patent than in Binns', as no mention whatever is made of steam or other warming agents for preparing the moulds for the reception

of the melted material, the water-tight boxes being merely fitted with wooden plugs underneath, by means of which the water could be run off when the cooling was completed. Each box of moulds, however (Palmer mentions 36 pipes to each frame), was of larger dimensions than the ordinary hand-frame, and was pivoted at the ends, to enable it to be easily turned when the candles were ready for extraction, simple means being devised for preventing any movement of the machine on its pivots until it was ready for this operation.

Morgan's Machine.—A couple of years later, however, in 1834, we come to an invention which, for completeness of detail and general efficiency of design, may fairly be regarded as the father of the present candle machine. In combination with the moulding frame, Joseph Morgan, of Manchester (the inventor), had means of ramming the candles out of the moulds, a sort of clamp to hold the candles when expelled, revolving knives for cutting the wicks from beneath the made candles, and nippers to hold the free wicks in their central position in the moulds pending the pouring in of more material. Thus Morgan's machine, having movable pistons through which passed the wick, was continuous wicking—that is to say, the expelled candle's place in the mould was taken by a fresh length of wick, proceeding from the inverted tip-end of the new-made candle, through the vacated mould and piston-tip to the reel or bobbin below the machine containing the bulk of the wick.

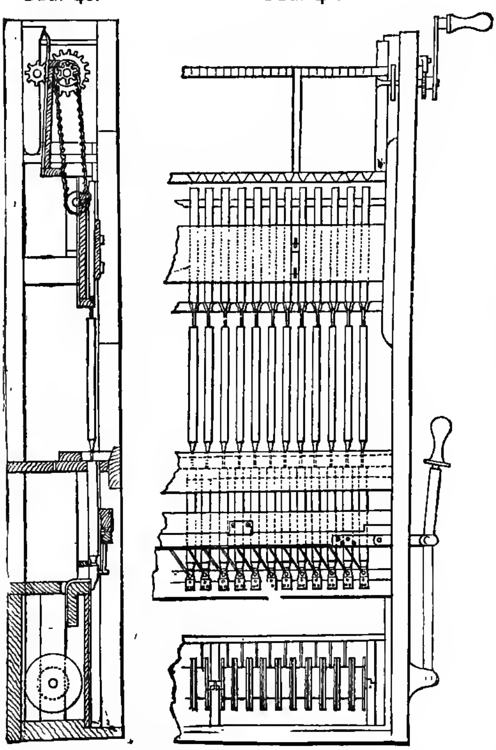
The action of the machine was briefly this:—The wicks being drawn through each mould, were held accurately in its centre by the nippers above. The whole frame was run upon a little railway to beneath a vat containing the substance of the candles to be made, where the moulds were filled in the usual manner. The machine was then "shunted" along the line out of the way until the candles had hardened, when the nippers being removed and the superfluous material scraped off, the frame was run along again (others having meanwhile undergone the filling operations, &c.) to a table furnished with rammers, and corresponding, in number and position, to the moulds in the machine. The frame, which is pivoted, was then tilted to a horizontal position, so that the piston or tip-ends of the moulds faced the rammers, which were then simultaneously forced against them, so ejecting, by the movable tip-piece, the candles from the moulds. The candles passed into a grooved divided box or clamp, hinged at one end and provided with a clasp at the other, so that on being shut down it held the candles firmly, and the wicks beneath being again centrally secured by the nippers, the portion above these and below the newly made candles was severed, so that, on removing the clamp full of candles, the machine was ready for refilling, as at first.

It is a pity that Morgan's specification gives no complete view of the machine in question, though amply provided with drawings of various parts; for this reason it is not easy to give a figure of reference to this invention, the full importance of which can be gauged by the foregoing description, and will be more readily comprehended when compared with the description of machines of a much later date.

Tuck's Machine.—Another considerable development of the candle machine was contained in the inventions of Joseph Tuck, of London, under his patents of 1837 and 1842. In Figs. 40 and 41 will be seen views of Tuck's machine, in which he employed steam and cold water for varying the temperature of the moulds (which Morgan apparently did not), but, like Morgan's, his machine was continuous wicking, and was certainly more self-contained and stationary. He had a single row of moulds only, and when

the candles were ready, they were drawn out of the mould from above, and not pushed from below, the extracted candles being held in a clamp, which though much like those in use at the present day, was not designed to hold the succeeding length of wick centrally in the moulds, and accordingly clips had to be employed for this purpose, as in Morgan's machine. The clamp of Tuck's, however, was used above the moulds, and the candles drawn into it, which was an improvement on this detail of Morgan's, though Tuck's clamp was only meant to hold the candles pending the arrival of another empty frame, which, being lowered from above, received them, prior to their wicks being severed.

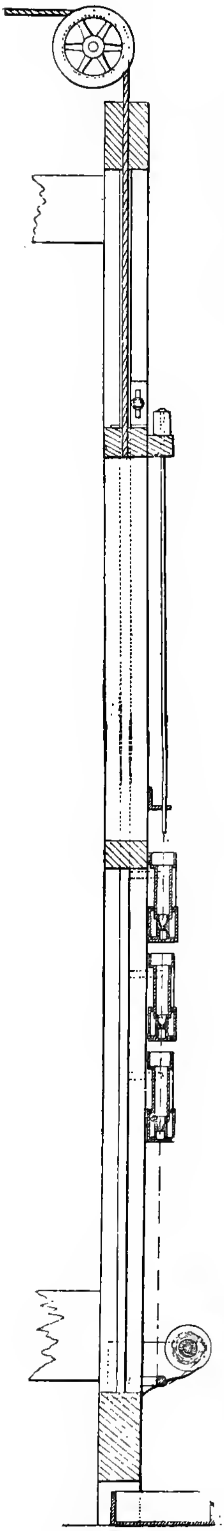
FIG. 40. FIG. 41.



Tuck's Candle-Moulding Machine.

Palmer's Second Machine.—William Palmer, in the course of years, followed up his patent of 1832 by many others, having apparently a genius for invention as regards candle-making machinery. Although much of the subject-matter of his specifications relates to unimportant and temporary detail, nearly all of which is now obsolete, there is a patent, dated 1845, which claims careful consideration. In the machine he there describes, Palmer arranged the apparatus somewhat after Morgan's fashion—that is, with an independent device for forcing the candles from the moulds; and he claims the combination of the nozzles of the candle moulds, so that they are the means of forcing the candles therefrom—which claim evidently implies the employment of the movable piston, covered by Morgan's patent of 1834. Palmer did not, like Morgan or Tuck, make his machine a continuous wicking one in the ordinary sense, but he so constructed the frames that they stood one above the other, three sets of moulds thus being in a vertically direct line. By this arrangement he was able to wick the three lineal moulds together, bobbins of the wick being below the respective moulds of the lowest frame, as indicated in Fig. 42, which also gives a general idea of the theory of the machine. In order to wick the whole frame-length, as well as the three sets of moulds, simultaneously, a modification of the method employed in wicking hand-frames was devised ; this consisted of a long bar, suspended horizontally and exactly over the top set of moulds. From the under side of this bar a number of long, hooked needles project, so distanced as to enable them to go down the centres of the moulds to take the wicks from the bobbins beneath these. This happened when the bar, by means of guides and pulleys, was lowered, and on its return journey the wicks were

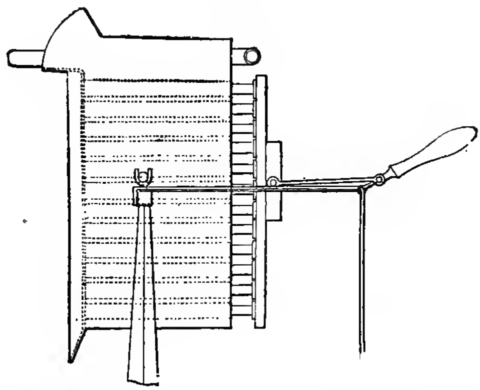
FIG. 42.



Palmer's Candle-Moulding Machine.

drawn up through the moulds. These were then filled, and, when the candles were set, the wicks cut between the sets of moulds. The frames were then detached from the machine and taken to a ramming bench, where the candles were expelled from the moulds. All the pistons being attached to one cross-bar, this was a simple matter, and Figs. 43 and 44 show the system of leverage, &c., employed. Palmer made use of steam and water for heating and cooling

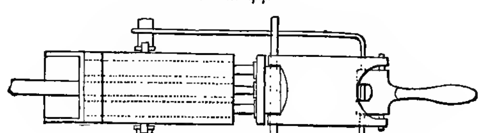
FIG. 43.



the moulds, and those shown by the plan at Fig. 44 do thus not quite compare with the single moulds shown at Fig. 42, but the wicking arrangement could obviously have been multiplied.

Stainthorp's Machine.—Ten years later, in 1855, John Stainthorp, of Buffalo, New York, obtained a patent in America, which embodied all the elements

FIG. 44.



Moulding Machine with Palmer's Candle Forcing Apparatus.

of the candle machine of the present day. The leading features in this, besides the manner in which various improvements were brought together, were the vertical ejection of the candles from the moulds, and the clamp to hold them in position centrally over the moulds, the machine being a continuous wicking one. There was no absolute novelty in Stainthorp's invention, with, perhaps, the exception of the clamp, but the happy constructive ability of the inventor combined existing forms of the

machine, and modified them to produce the compact apparatus described in his patent, diagrammatic views of which are shown at Figs. 45 and 46. The clamp in question was not so much designed to grasp the candles, but was made to support them, and so avoid the risk of fracturing or bruising their surfaces. It consisted of two similar pieces of wood, having notches cut in their inside surfaces almost the entire depth of the piece, (about four inches), the notches being graduated off, so that after the candles

FIG. 45.

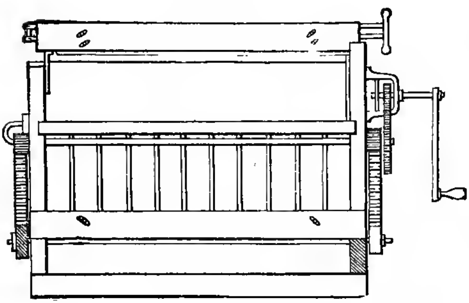
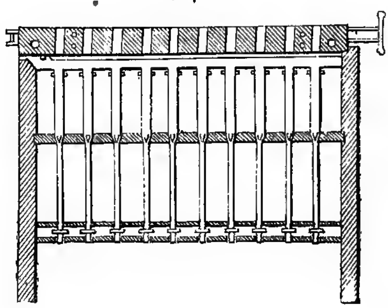


FIG. 46.

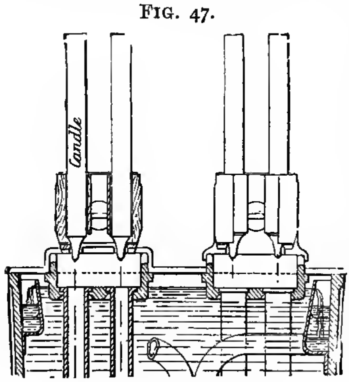


Stainthorp's Candle-Moulding Machine.

had passed between them, and the clamps closed together, the tips of the candles rested on the graduated parts, the notched incision closing round the shaft of the candle, but not tightly. The action will be best understood o reference to Fig. 47.

Humiston's Machine.—Humiston's patent followed closely on that of Stainthorp, too closely to allow of the idea of an infringement, although the inventions were practically identical. Willis Humiston, like Stainthorp, was an American, of Troy, New York (though the latter is generally supposed to have been a Yorkshireman by birth), and his machine was, like Stainthorp's, continuous wicking, and had also a clamp to hold the ejected candles centrally over the moulds. Humiston's machine is shown at Fig. 48, and perhaps the most interesting detail is the clamp (see Fig. 50 in plan), and of which Figs. 48 and 49 also show views. It will be seen that the clamp (somewhat like Stainthorp's in construction) consisted of two pieces of wood for each row of candles, similarly shaped, having semicircular notches cut on their inside faces, the two parts being kept asunder by springs, to admit of the passage of the candles between. The insides of the notches were coated with india-rubber, to avoid hurting the candles, and when these were duly in position, the handles of the clamp were turned, and cam-shaped projections on the parallel handle rod both squeezed the inside pieces of wood outwards, and drew the outside pieces inwards, making the candles secure in their embrace. This was not quite so good a method as Stainthorp's, as by possible unequal pressure along the clamps candles were apt to get broken, and in any

FIG. 47.

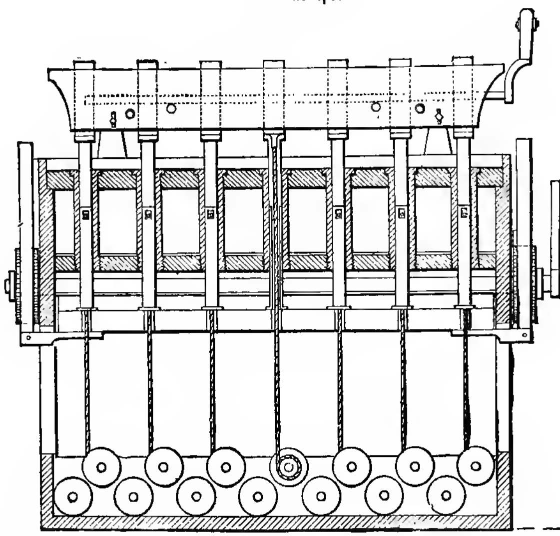


Part Section of Stainthorp's Candle Machine.

case the tightly holding clamp must have injured the smooth surface of the candles more or less.

Humiston's American patent machine had a somewhat complicated

FIG. 48.



system of pulleys and ropes for raising the candles simultaneously from the moulds, which was also the means employed for raising the lifting-plate of Stainthorp's machine; but the modified apparatus shown by Morfit, in his

FIG. 49.

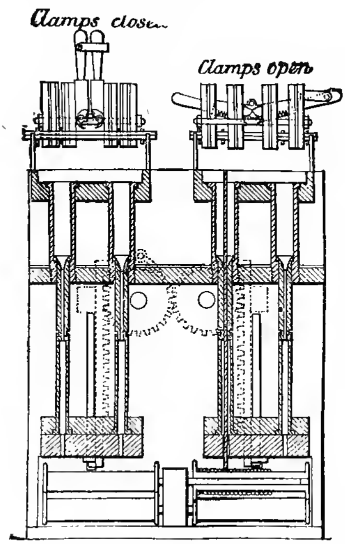
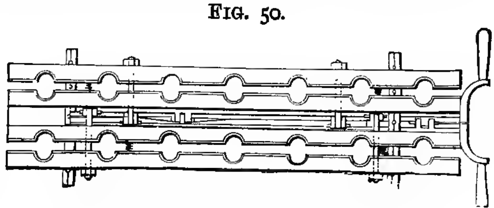


FIG. 50.



Humiston's Candle-Moulding Machine.

"Treatise on Soap and Candles," gives a rack and pinion to serve this purpose, as will be noticed in Fig. 49. The bar to which the pistons were attached was made somewhat elastic, so that, on being started, the candles at the ends began to come out a little before those towards the centre of the machine, any sudden jar on them being by this means avoided. Springs were also set between the outside of the pistons and the lifting plate, so as to ensure a tight fit of the former in the moulds, and thus prevent leakage.

It will be observed that both Stainthorp and Humiston deserve much credit for their inventions independently, and though Stainthorp has priority of claim by a few months, Humiston's machine in some of its details was

more valuable and well thought out. It is noteworthy, that in 1857, both these American patents were repeated in England through different agencies, the real inventors' names being in neither case disclosed, and a close observation of the respective specifications of the agents, W. E. Newton and J. T. Pitman, reveals without a doubt the fact that the former was acting for Humiston, and the latter, filed but three days later, for Stainthorp.

FIG. 51.

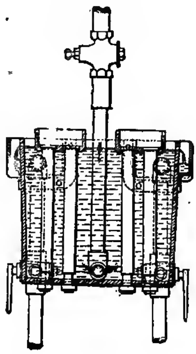
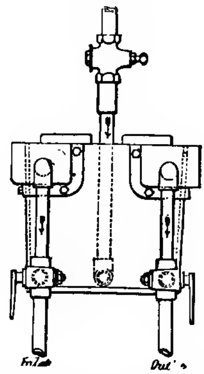
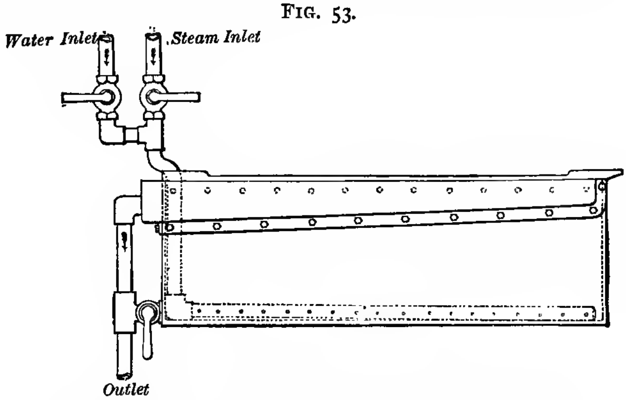


FIG. 52.



In 1856, Mr. E. A. Cowper, who was the consulting engineer to Price's Patent Candle Company at that time, patented a means of ejecting candles from their moulds by compressed air, and machines with this contrivance were employed by that company for many years, supplanting those older forms of Joseph Morgan's, which we have already described. The former have, however, now long since given place to machines having

FIG. 53.



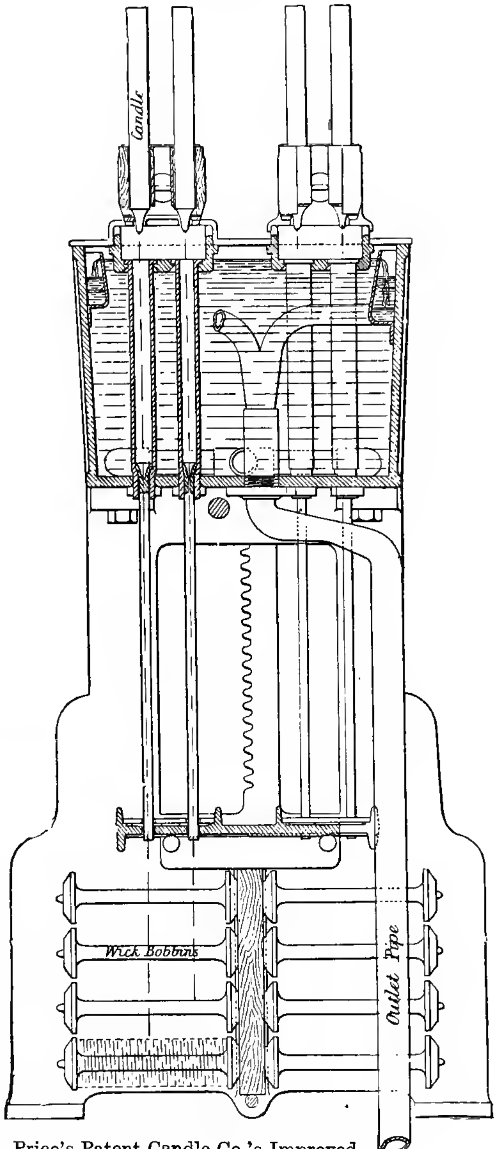
Morgan's Steam and Water Circulating Arrangement.

mechanical means for expulsion of the candles, of which the constructions of Stainthorp and Humiston were the forerunners.

Stainthorp's and Humiston's inventions bring in reality the historical view of the candle machine to a close, since in almost every particular the machines of 1892 are identical with those of their date, subject of course to such minor improvements and modifications as the experience of candle-makers and their technical engineers have from time to time devised. Foremost among the improvements mentioned may be quoted the better arrangements for equalising the distribution of the heating and cooling

agencies in the tank containing the moulds. Down to 1859, it was considered sufficient merely to provide inlets and outlets in the tanks for introducing and emitting the steam or cold water, irrespectively of the course taken by currents of these inside the tank, which, however, was found by subsequent experience to run in a direct line from inlet to outlet, cooling or warming those moulds in their immediate path to a much greater degree than those outside this line. Consequently the candles from such moulds as did not obtain sufficient variation of temperature, were difficult to expel and not so satisfactorily made as those which had been properly treated—that is to say, particularly candles made from paraffin, since stearine candles, being moulded from the material when all but at solidifying point, did not need so much attention in this respect. In 1859, Morgan designed a machine having perforated pipes throughout the length of the tank, by which means a better circulation of the steam and water was obtained. Some time after, the tank was arranged to permit an overflow of the water at various points at a level near the top of the moulds, which was drawn off by pipes or drains placed outside the tank, as will be seen by Figs. 51, 52, and 53.

Fig. 54.



Price's Patent Candle Co.'s Improved Candle Machine.

A much neater, more effective, and also economical improvement has been introduced of late years by Price's Patent Candle Company and is illustrated by Figs. 54, 55, and 56. The steam and water inlets are placed at the lower corners of the tank, the main supply pipes being beneath instead of overhead as usual. The side-drains are inside the tank, the water being carried off by a pipe at one end. The pipes from both of the side-drains join together in the centre and pass out through the bottom of the

tank and down the inside of one leg of the machine, to the main drain below the floor, the whole system of circulation being thus kept within the walls of the machine.

American and Continental practice shows but a slight variation on the model English machine, as will be gathered on examination of the following illustrations, which represent at Figs. 57, 58, and 59 an English machine;

FIG. 55.

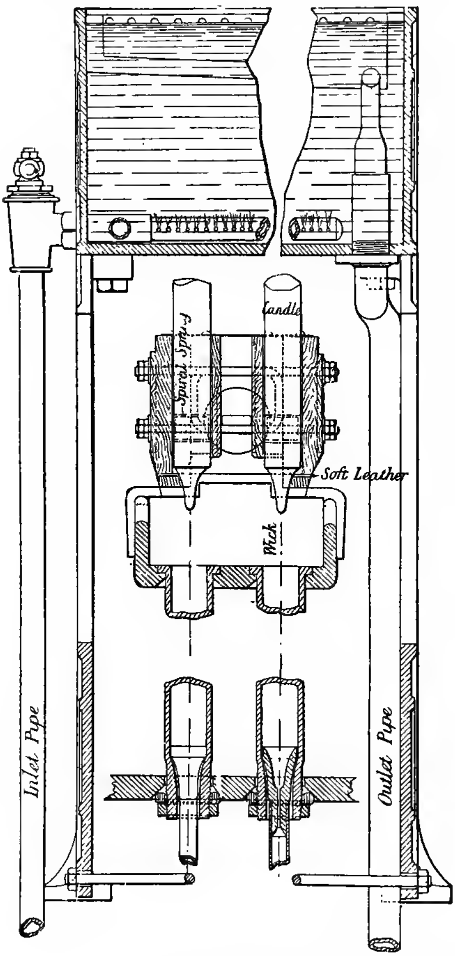
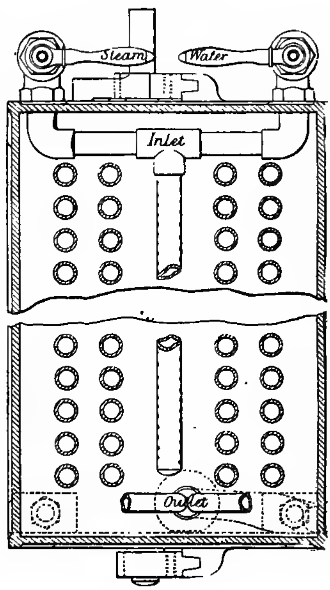


FIG. 56.

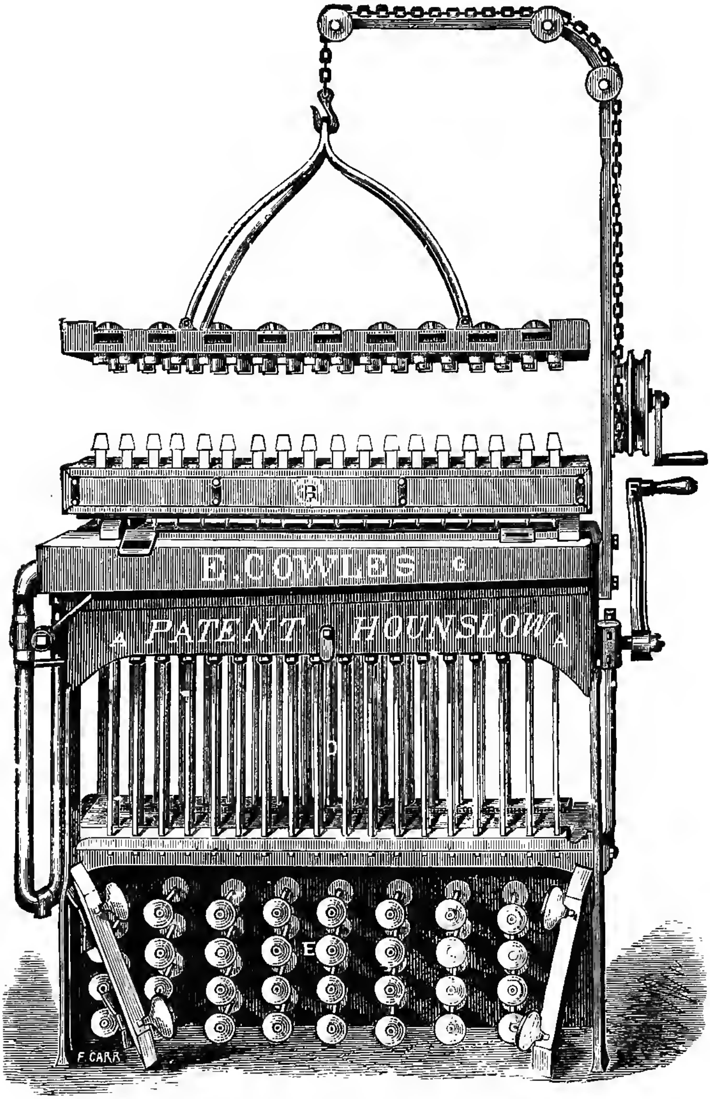


Price's Patent Candle Co.'s Improved Candle Machine.

Fig. 60 (p. 91) is of American make, whilst Figs. 61 and 62 (p. 92) are French and German respectively. It will be noticed that the latter are provided with coverings for the bobbins, the French machine having a cylindrical metal casing, the German a platform over the collective bobbins. These are intended to keep the wick from dust and dirt, leaks from the tank, &c., it being highly essential that the cotton in the candle should be absolutely free from dampness or foreign matter. In the Ohio Silver Plate Company's

machine, Fig. 60 (p. 91), the bobbins are placed vertically and do not revolve, the wick being drawn from them somewhat after the way that silk is taken from a cocoon.

FIG. 57.



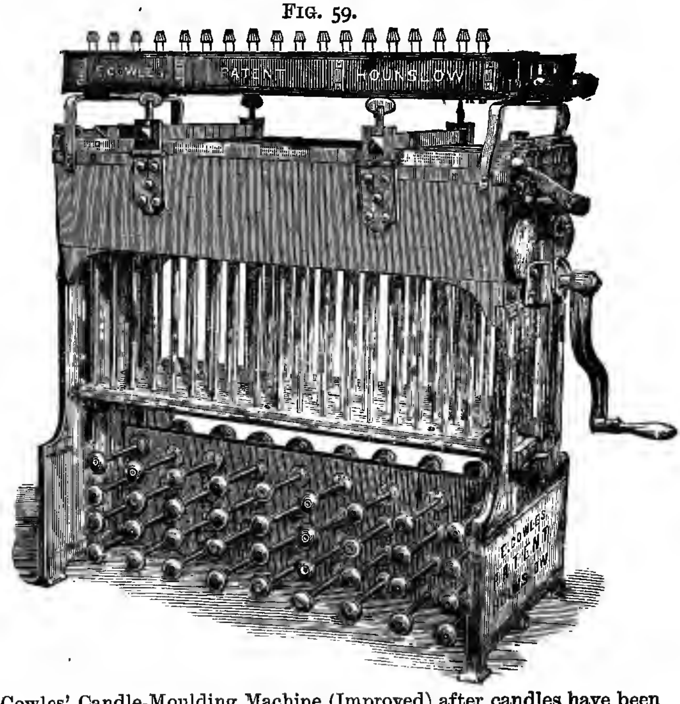
Cowles' Candle-Moulding Machine.

In following up the progress of the candle machine from infancy to maturity, so much description has to be given to details commanding special attention, that perhaps general construction has been put somewhat in the shade. It will not therefore be amiss, with the above figures to guide us, to give a general outline description of the candle-making machine of the present day.

FIG. 58.

Cowles' Candle-Moulding Machine (Improved) ready for Filling.

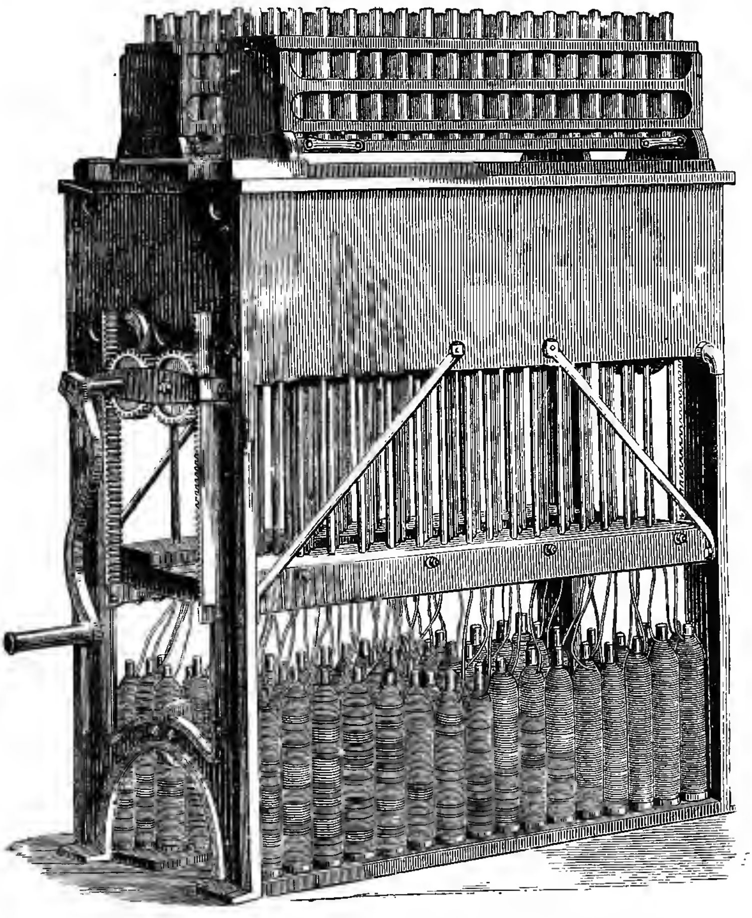
FIG. 59.



Cowles' Candle-Moulding Machine (Improved) after candles have been ejected with clamps above.

The water-tight tank, so often referred to above, is supported on a framework of cast iron, and is from three to five feet long, about 18 inches across, by a foot deep. It is usually divided down the centre, each half containing a range of two rows of moulds. The moulds traverse the tank vertically and are soldered into the trough end, being secured under the bottom of the tank by a screw-nut, the mode of fixing which is similar to that shown at A, Fig. 63 (p. 93). A cross plate of the frame at its base

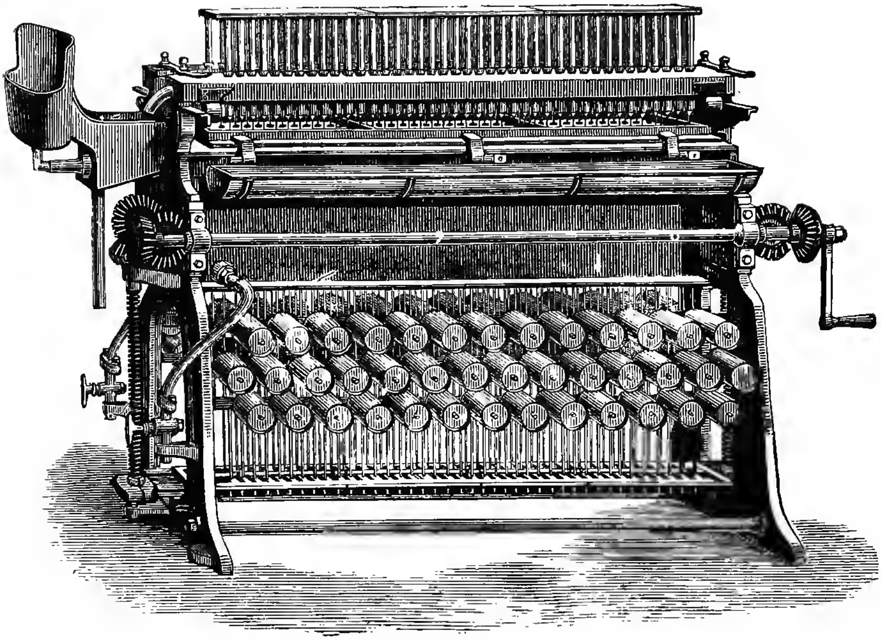
FIG. 60.



The Ohio Silver Plate Company's Candle-Moulding Machine.

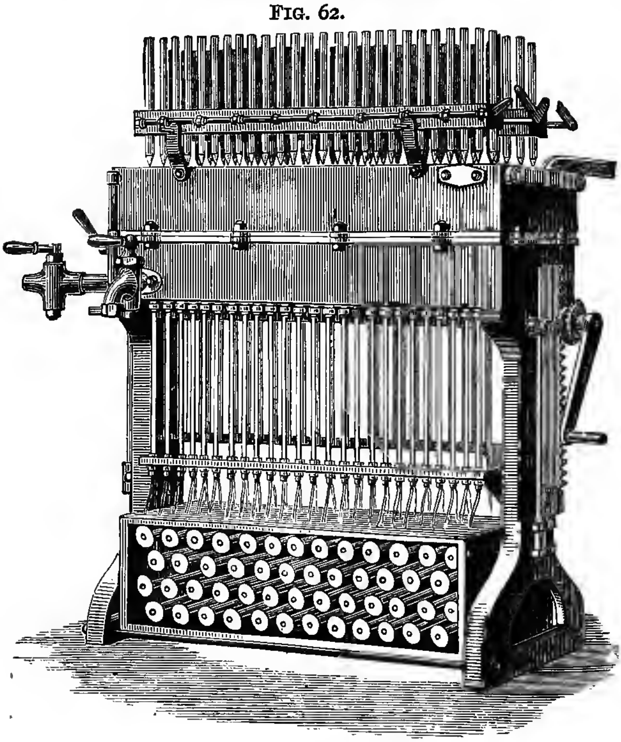
(which serves to tie the two end legs or supports) has on each side a number of horizontal axes corresponding with the number of moulds, each axis being placed respectively beneath each mould. On these are put the wooden bobbins wound with the prepared wick. From the bottom of the moulds project the piston stems, to the upper ends of which are attached the tips of the mould, the lower end being screwed to the "lifting-plate," which is just above the frame of bobbins, and which is guided by the ends or legs of the machine, grooved for this purpose. There is a rack and pinion on both sides of the machine, the pinion being secured vertically to the lifting-plate, whilst the former has, on one side of the machine, a long lever, which serves

FIG. 61.



Morane's Candle-Moulding Machine.

FIG. 62.



Wunschmann's Candle-Moulding Machine.

to raise the lifting-plate, and with it the pistons, thus expelling the candles from the moulds. The pistons, with their stems, are of course hollow, to admit the passage of the wicks. These are, in the first instance, drawn through by hand, and secured centrally above the moulds by little clips, a sufficient number thereof being on a light framework, which can be removed or thrown back on hinges after the first filling. When this is completed and the clips removed, the surplus material is scraped off, and the trough surmounted by the clamps (already described at length), the candles coming up into their respective places therein. By turning the handles on the clamps the candles are secured, when the lifting-plate is allowed to descend taking the pistons with it, but leaving the moulds with a length of wick down the centre, which was drawn from the bobbins as the last made candles were pushed out. The moulds can now be refilled, and when this material has set the wicks of the clamped candles may be snipped below and the candles removed. The surplus material is again scraped from the trough, and the above described series of operations repeated until the supply of wick on the bobbins is exhausted.

Fig. 63.

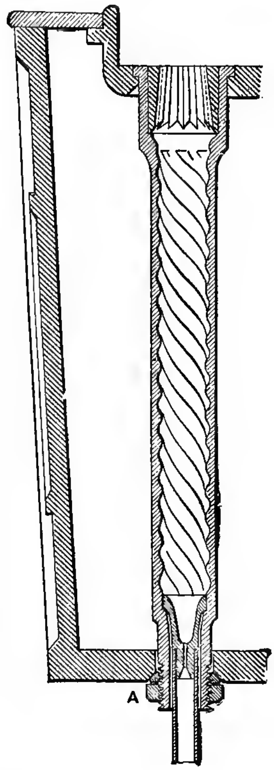
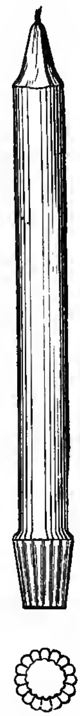


Fig. 64.



Field's Self-fitting End.

Self-Fitting Ends.—In 1861, John Lyon Field patented his invention for giving the ends of candles a conical shape to ensure their fitting tightly into most ordinary candle sockets. The patent was comprehensive, but many inventors have since claimed variations on this invention which were really covered by Field's specification. After many experiments, the now well-known self-fitting end, Fig. 64, was adopted, and since the expiration of the patent the corrugations have assumed many forms, according to the experience of the manufacturer. The latest improvement is that of Wigfield's, whereby a saving of material is secured to the benefit of the duration of the candle, and the butt itself is found to fit very firmly into the sockets of most candlesticks. (See Fig. 65.)

Fig. 65.

Wigfield's Self-fitting End.

Machines to construct these self-fitting candles must have special appliances for moulding the ends, since it will be readily understood that the inverted cone forms an impediment in the way of expelling the candles.

Edward Cowles, who first made the machines for J. C. and J. Field, employed a casting containing the upper end of the butts, which was

removed by a chain and pulley when the material had set, the candles being then pushed out in the ordinary manner. Since then, however, the ingenuity of candle-machine makers has brought forward a number of methods for securing a simple and effective device to extract the self-fitting ends from the moulds, of which, perhaps, the best at present is that of W. E. Hutt, patented in 1881, and shown by Figs. 66, 67, and 68, wherein

FIG. 66.

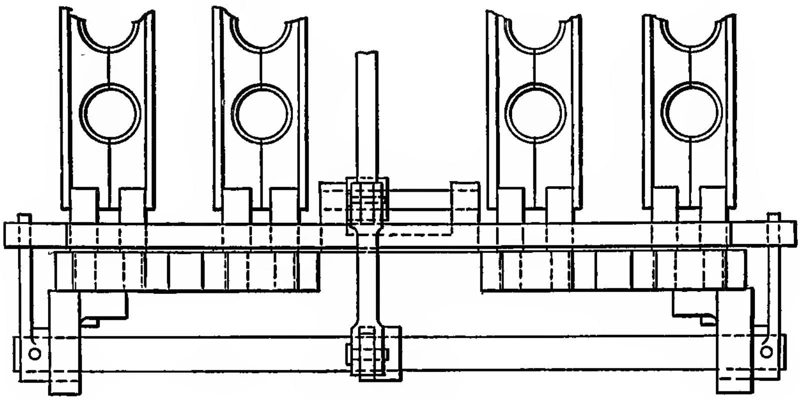
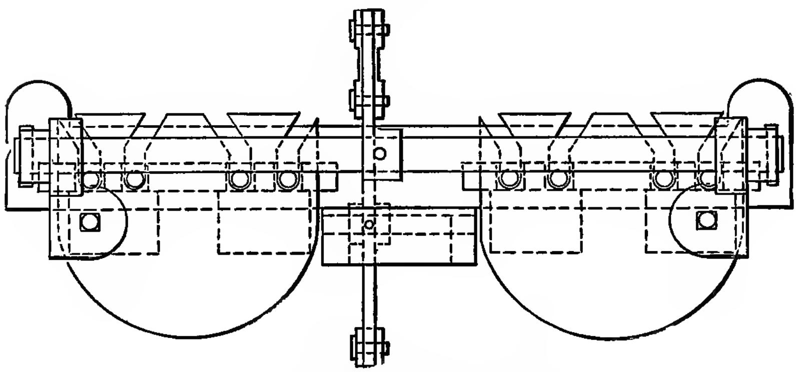


FIG. 67.



Hutt's Self-fitting Moulding Machine.

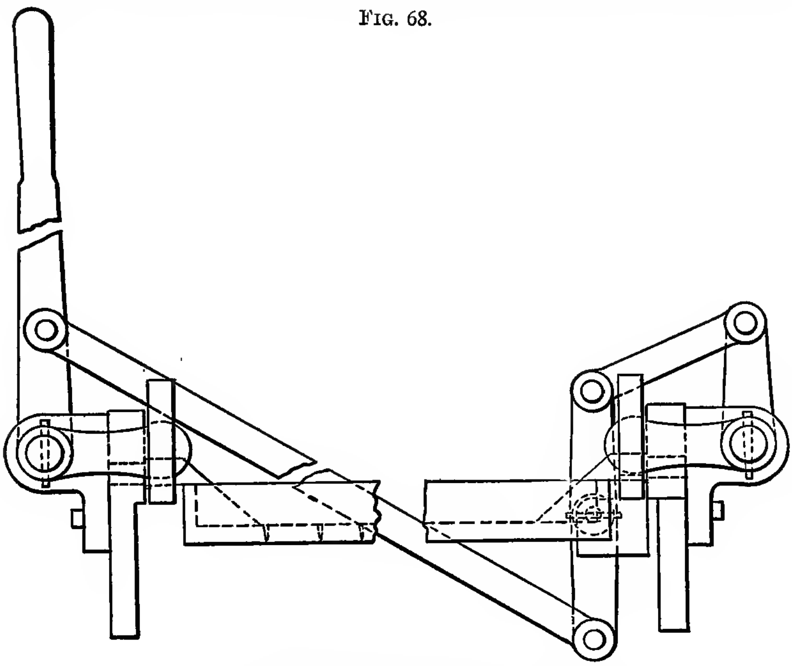
the moulds for the butts are cast in one piece, made up of two halves, which by turning a lever are raised in slotted guides so that they come apart sufficiently to allow the complete candles to pass up between them. When these are duly clamped, the lever is reversed and the two halves of the moulds drop down the slots, coming close together again on the surface of the moulds, which are then ready for another filling.

Morane, of Paris, has also effected the desired end, but in his case the moulds are cast entirely in one piece, a little slot passing from the inside edge of the mould to the outside of the casting, to enable the wick to come through. These castings are formed as bars, having a handle at each end, by which they are entirely removed as they lie flush on the surface of the moulds. A slight objection to this method is that paraffin being so very fluid when melted, unless the two surfaces are in actual contact throughout, it leaks between, and necessitates the use of hand labour to subsequently

trim the candle. This, however, is necessary in any case to a certain extent, owing to the material forming a little wedge in that slot mentioned which is left for the passage of the wick.

Fancy Candles.—In the great variety of fancy candles that are now in the market, there are many forms adaptable to machine moulding, the two chief of which are the spiral or cabled form of candle, and the fluted. The latter presents no special difficulties in manufacture, the moulds being merely grooved according to the requirements of the candle to be made. The former, however, is not so easy to arrange for, provision having to be allowed for extracting the twisted candles from the moulds. Morane's original patents of 1871 all admit of this with much simplicity and efficiency, so much so, indeed, that

FIG. 68.



Hutt's Self-fitting Moulding Machine.

120 candles can be simultaneously taken from the machine with the same ease as from one of the ordinary construction. The moulds are cast with the female thread, as it were, of the spiral, and the tip, fitting the mould closely, is naturally of a corresponding plan configuration, and must follow the twist of the mould as it ascends, pushing the candle with it. To this end, instead of being firmly fixed to the lifting-plate, the pistons are permitted to revolve therein, and certainty of action and steadiness are further ensured by a little additional thread or worm of wire of the same pitch as the mould-threads, surrounding the piston-stem below the moulds, into which it works when the candle is some distance up. Fig. 69 shows a cable candle made by this machine. These were originally, and are still to a great extent, turned to this contour by a hand-lathe of peculiar construction, the invention of the late Arthur Field, this lathe being also capable of cutting candles to various patterns, and of infinite and beautiful variety.

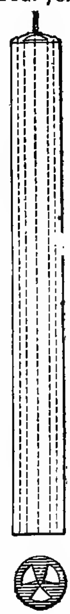
A last modification of the candle machine is employed for producing the "perforated" candles, which have two or more channels running down their

length to receive the melted grease when the candle is inclined to gutter. Such a candle is shown at Fig. 70, and to produce it the tip on the piston has a corresponding number of shafts or prongs to the channels to be made (usually three) vertically in the moulds, and these of course rise and fall with the piston.

FIG. 69.

Night-Lights.—A brief description of the machinery employed in the production of these useful little lights may well be included in this article. The night-light, as is well known, usually consists of a body of material of the substance of which candles are made—generally cocoa-nut oil, stearine, or paraffin, or mixtures of them—being circular in form, and about $1\frac{1}{2}$ inch across, by $1\frac{1}{4}$ deep. The wick is very fine, whereby the light lasts a long time, the general duration being six, eight, or ten hours. It is passed through and held by a little flat "sustainer" of tin or other suitable substance, at the base of the night-light, and the whole either encased in a cardboard cup of corresponding dimensions, and burnt in a saucer containing a small quantity of water, or else consumed in a glass dish just large enough to hold it, in which case no water is necessary. For many years night-lights were entirely hand-made, and a large proportion are still so manufactured, the sustainer and wick being secured to the bottom of the cup and the molten grease skilfully poured in up to the brim. With competition and increase of the trade, however, it has become necessary to produce a neater and better light in greater quantities, and to this end machines have been devised to suit the various forms of night-light, whether for decoration or ordinary household uses. The framework of a night-light machine resembles that for candle-making in that it has a water-tank carrying a number of hollow moulds, and the lights are ejected by pistons. Here, however, the resemblance ceases. As yet, the night-light machine is not continuous wicking.

FIG. 70.



The pistons are arranged with pins projecting upwards from their centres, and these form passages for the wicks, which are introduced subsequently. In the latest form of machine, the pistons are capable of being graduated down the mould, to suit the size of light to be made, and the "blanks" (as the cylindrical lumps of made-up material are termed), are expelled by means of a lever, instead of the more cumbersome rack and pinion motion. Otherwise the process is as in candle-moulding. The blanks, of which some 120 to 160 are turned out at once, are from thence treated by hand. The wicks, already prepared with the sustainers, are passed through the little passage in the blank left by the pin in moulding, and the whole put into the cardboard cup. To further sustain the wick and securely unite the separate parts, the wick is often passed through the bottom of the cup and caused to adhere thereto by the application of a little sealing-wax.

A cheap form of this class of candle, known as a "bucket light," is formed of cheap stearine, run by hand into shallow tin cylinders standing on a level marble slab, the sustainer and wick standing upright in the centre, as roughly adjusted by eye. These are much used for illuminations in coloured lamps, in gardens, &c.

We are indebted to the editors of "Engineering" for many of the foregoing illustrations, and some of the material for the descriptions.

SECTION IV.

THE PETROLEUM INDUSTRY.

BY

BOVERTON REDWOOD.

CHAPTER I.

I. General History of Petroleum.

ONE of the earliest descriptive references to petroleum was made by Herodotus, who about the year 450 B.C. gave an interesting account of a well at Arderrika, thirty-five miles from Susa, producing "asphalt, salt and oil," the mixture being drawn from the well in a bucket made from a wine-skin, and poured into a receptacle, when the asphalt and salt became solid, and the oil, which was black and had a strong odour, separated. This writer also describes the pitch spring of the Island of Zante, and mentions that bitumen brought down by the waters of the Is and Euphrates was employed in the building of the walls of Babylon. Aristotle, about 350 B.C., Strabo, 25 B.C., Pliny, about A.D. 50, Plutarch, about A.D. 66, and others, describe deposits of bitumen occurring on the eastern shores of the Adriatic Sea. Strabo, and Diodorus of Sicily (about 25 B.C.) refer to the use by the Egyptians, for the embalming of their dead, of the bitumen found in the valley of the Indus, and the former relates how this substance rose to the surface of the Dead Sea during or after earthquakes. Pliny and Dioscorides also mention the oil of Agrigentum, which was used in lamps under the name of Sicilian oil. Plutarch records that a Macedonian, who had charge of Alexander's baggage, dug on the banks of the Oxus, and that "there came out oil which differed nothing from natural oils, having the glosse and fatness so like as there could be discovered no difference between them." The Book of Genesis contains a distinct reference to the use of petroleum in the building of the tower of Babel, the word "slime" in the English version being ἄσφαλτος in the Septuagint and *bitumen* in the Vulgate, and there is a tradition that the material for the purpose was collected from the so-called pitch fountain of Oyun Hit on the Euphrates. Notices of petroleum springs and gas wells are stated to occur in Chinese records of great antiquity, and there is little doubt that natural gas was employed as fuel in China centuries before the Christian era. The existence of petroleum oil and gas in Japan has also been known for a long period, and Mr. Lyman, in his first report on the Geological Survey of Japan, published in 1877, states that the oil wells of Echigo are supposed by the inhabitants to have been dug several hundred years ago. He adds: "It is said in the Japanese history called 'Kokushiriyaku' (I am told) that rock oil (or 'burning water') was found

in Echigo in the reign of Tenjitenno, which was 1200 years ago, or about A.D. 615, and that was probably at Kusôdzu, where there are still many natural exposures, as well as dug wells. The name of the place, Kusôdzu, is the name given in the country to rock oil, and it means 'stinking water'; and the very fact that the word is by contraction changed from its original form, Kusaimidzu, shows of itself considerable antiquity. Natural gas even is called Kaza Kusôdzu, the first two syllables meaning wind or air, and evidently identical etymologically with our very modern western word gas."

Gibbon records that when Heraclius (A.D. 624) wintered at the mouth of the river Kura, seventy miles south of Baku, his "soldiers extinguished the fire, and destroyed the temples of the Magi." This is no doubt a reference to the "eternal fires" at Surakhani, on the Apsheron peninsula, which have probably been frequented by fire-worshippers from the time of Zoroaster, who lived not later than about 600 B.C. A temple is now standing on the spot, and the petroleum gas issuing from the earth can still be ignited on the altars. This temple is, however, considered to be of Hindu origin and not more than two centuries old. A similar temple exists in the Punjab.

Marco Polo, who wrote in the thirteenth century, is supposed to have referred to the petroleum of Baku, when he stated that there was in this neighbourhood an abundant spring of oil, not good for food, but good to burn or to anoint camels that had the mange. In 1436, petroleum from the shores of the Tegernsee, in Bavaria, was employed medicinally under the name of St. Quirinus' oil, and in 1640 Francesco Ariosto claimed to have successfully treated cases of itch in men and animals with petroleum which he had discovered at Mont Libis, in the Duchy of Modena. The natural gas at Surakhani, already alluded to, was described by Jonas Hanway, in the middle of the eighteenth century, as giving a flame in colour and gentleness not unlike that of a lamp that burns with spirit, only more pure, and sometimes rising to a height of eight feet when the wind blows. Tcheleken Island, on the opposite side of the Caspian Sea, was also described by Hanway as being peopled when he visited it in 1743 by thirty-six families, who owned several wells of naphtha, and carried on a brisk trade in selling the oil to Persians, Turcomans and others, having two dozen large boats employed in the transport of the liquid.

According to Professor Peckham,* the earliest mention of the occurrence of petroleum in North America is dated 1629, though undoubtedly the existence and certain uses of petroleum were well known to the Indians very long before. In the year mentioned, a Franciscan missionary, Joseph de la Roche d'Allion, who had crossed the Niagara river into what is now the State of New York, wrote a letter (published in Sagard's "Histoire du Canada," in 1632) in which he described the oil springs and gave the Indian name of the place, which he explained to signify "There is plenty there." In 1750, the commander of Fort Duquesne wrote to General Montcalm, describing the ceremonies of the Seneca Indians as ending in the ignition, by means of a torch, of the scum which covered the surface of a small stream flowing into the Allegheny. About the same period, or a few years later, Peter Kalm published in Swedish a book of travels, in which was a map showing correctly the position on Oil Creek of the petroleum springs which afterwards became so famous.

In 1765, the English Government sent an embassy to the Court of Ava, in Burmah, and in the journal of the embassy Major Symes thus refers to the petroleum wells on the Yenangyoung ("Earth-oil Creek"), a tributary of the Irrawaddy:

* Census Report on the Production, Technology, and Uses of Petroleum. Washington, 1884.

"After passing various lands and villages, we got to Yenangyoung, or Earth-oil Creek, about two hours past noon. We were informed that the celebrated wells of petroleum, which supply the whole empire and many parts of India with that useful product, were five miles to the east of this place. The mouth of the creek was crowded with large boats waiting to receive a lading of oil, and pyramids of earthen jars were raised in and around the village, disposed in the same manner as shot and shell are piled in an arsenal. This is inhabited only by potters, who carry on an extensive manufactory, and find full employment. The smell of the oil is extremely offensive. We saw several thousand jars filled with it ranged along the bank; some of these were continually breaking, and the contents, mingling with the sand, formed a very filthy consistence." At this time there were stated to be 500 wells, yielding in the aggregate 90,900 tons per annum.

The existence of petroleum in Galicia is said to have been discovered in 1771, in what is now the oil field of Sloboda-Rungurska, near Kolomea; but the crude oil was no doubt collected in a primitive fashion, long before that time, for use as a lubricant, and as a remedial agent for outward application in cases of cutaneous disease. In 1788, Winterl examined a thick black variety of petroleum, occurring between Peklenicza and Moslowina, in Hungary; and in 1791, Martinovich gave an account of a dark-brown petroleum found in Galicia. According to Dr. Gesner, the existence of asphaltum and solid bitumen at Santa Barbara, in Southern California, has been known since 1792. In 1811, the pitch lake of Trinidad, near the mouth of the Orinotas, was visited and described by Dr. Nicholas Nugent. Mr. E. St. John Fairman states that the streets of Genoa were first lighted with petroleum from Miano, in the Duchy of Parma, in the year 1802. The crude petroleum from the locality was examined by Saussure in 1817.

Mr. Charles A. Ashburner, geologist in charge of the Pennsylvania Survey, is of opinion that possibly natural gas was first obtained commercially in the United States at Fredonia, Chatauqua Co., New York, where a well was sunk on the bank of Canadaway Creek, near the main street bridge, in 1821, and sufficient gas was obtained for thirty burners, the inn being illuminated with the gas when General Lafayette passed through the village about 1824.

As far back as 1810, or between that date and 1818, Hecker and Mitis, who owned wells in the Drohobicz district in Galicia, are reported to have distilled the oil, and the Alstettering, in Prague, is stated to have been lighted with the product. The refinery which supplied the total requirements of the city in question (300 cwts. per annum) was situated at Kabicza, and the oil appears to have been sold at 35 florins per cwt., but the company which carried on this refinery suspended operations in the year 1818. Persian petroleum was distilled by Unverdorben in 1829, and a small quantity of solid "fat" obtained, and in 1831 Christison and Gregory obtained paraffin from Rangoon petroleum. In 1836, the petroleum from the Tegern Lake in Bavaria, already referred to as being known by the name of St. Quirinus' oil, was examined by Kobell.

In 1833, Professor Silliman published the following account of the oil-spring of the Seneca Indians, near Cuba, New York.

"The oil-spring, or fountain, rises in the midst of a marshy ground; it is a muddy and dirty pool of about eighteen feet in diameter. The water is covered with a thin layer of petroleum, giving it a foul appearance, as if coated with dirty molasses, having a yellowish-brown colour. They collect the petroleum by skimming it, like cream from a milk-pan. For this purpose they use a broad flat board, made thin at one edge like a knife; it is moved flat upon, and just under the surface of, the water, and is soon covered by a thin coating of the petroleum, which is so thick and adhesive

that it does not fall off, but is removed by scraping the instrument on the lip of a cup. It has then a very foul appearance, like very dirty tar or molasses, but it is purified by heating and straining it while hot through flannel or other woollen stuff. It is used by the people of the vicinity for sprains and rheumatism, and for sores on their horses, it being in both cases rubbed upon the part."

In 1847, Mr. James Young, whose name is so well known in connection with the Scottish shale oil industry, obtained the right of working a petroleum spring in the Riddings Colliery, at Alfreton, in Derbyshire, to which his attention had been directed by Mr. Lyon Playfair, now Lord Playfair. The supply of the raw material soon became exhausted, and Mr. Young was forced to seek for another source of the products he had manufactured.

After the failure in 1818 of the company formed to refine petroleum in Galicia, no further attempts to develop the industry in that country appear to have been made until the year 1852, when a person named Schreiner, carrying on the business of manufacturing cart grease from crude petroleum, collected, when boiling the material, the drops of liquid which condensed on the cover of the vessel, and took some of the strong-smelling oil to an apothecary named Mikolasch, who had an assistant of the name of Lukasiewicz. The latter, with his colleague Zeh, treated the liquid with sulphuric acid and caustic soda, and found that the refined oil burned well. Renewed attention being directed to the subject, in the following year Galician petroleum was substituted for candles in the lighting of the station of the Emperor Ferdinand's North Railroad, and in 1854 this oil became an article of commerce in Vienna.

In 1854, Mr. Warren de la Rue obtained a patent for a process of manufacturing paraffin and other products from petroleum. The crude oil with which he experimented was obtained from the Yenangyoung district in Upper Burma, and was imported under the name of Rangoon oil. For some time afterwards the refining of this material was carried on by Price's Patent Candle Company and Messrs. Charles Price and Co., but the industry ultimately became unprofitable.

II. Historical Account of the Development of the Petroleum Industry in the United States.

The drilling of the celebrated Drake well in the United States, in the year 1859, marks the commencement of the rapid growth of the petroleum industry in that country. Prior to that event, the supplies of crude petroleum had been so scanty that the American mineral oil refiners were compelled to employ bituminous coal as the source of their various products. Attention had, however, for some time been given to the question of obtaining the petroleum stored in the earth. Numbers of wells drilled for brine yielded petroleum in small quantity, and one such well near Burkesville, Kentucky, drilled in 1829, produced several barrels of oil at intervals of five minutes, the oil so obtained being sold in bottles as American medicinal oil. At length, in 1854, a tract of land 105 acres in extent, on what was known as Watson's Flats, embracing the island at the junction of Pine and Oil Creeks, was secured for the purpose of systematic experimental drilling. This property was ultimately leased to an organisation termed the Seneca Oil Company, who employed Mr. Drake to drill an artesian well for oil. After overcoming many preliminary difficulties arising from inexperience, Mr. Drake "struck oil" on the 28th August 1859, the drill entering a cavity in the rock at a depth of 33 feet and falling six inches. On the following day (Sunday) Mr. William Smith, who with

his two sons had been employed in drilling, found the bore-hole nearly full of a liquid, and on drawing up a small quantity in a tin cup ascertained that the fluid was petroleum. After this successful result, drilling for oil took place with great activity, the operations being, however, at first confined to the valley of the Allegheny and its tributaries. From this date, coal-oil refiners began to substitute crude petroleum for bituminous coal, and the distillation of the latter material for oil soon ceased to be profitable. In 1865, the area of the producing territory was very considerably enlarged, wells being drilled over a tract of country extending from Manitoulin Island to Alabama, and from Missouri to central New York. In Pennsylvania, oil was also found at Smith's Ferry, on the Ohio river, in Beaver, and in the hill region lying in the angle formed by Oil Creek and the Allegheny river, from Tidioute across to Titusville. Henry states that: "At the end of 1861 commenced the flowing-well period, with an addition to the production of 6000 or 7000 barrels a day. The price fell to 20 cents a barrel, then to 15 cents, and then to 10 cents. Soon it was impossible to obtain barrels on any terms, for all the coopers in the surrounding country could not make them as fast as the Empire well could fill them. Small producing wells were forced to cease operations, and scores of operators became disheartened, and abandoned their wells. The production during the early part of 1863 was scarcely half that of the beginning of 1862, and that of 1864 was still less. In May 1865, the production had declined to less than 4000 barrels per day. Commencing at Titusville, in 1859, the tide of development swept over the valley of Oil Creek, and along the Allegheny river above and below Oil City for a considerable distance; then Cherry Run in 1864. Then came Pithole Creek, Benninghof, and Pioneer Run; the Woods and Stevenson farms, on Oil Creek, in like succession, in 1865 and 1866; Tidioute and Triumph Hill in 1867, and in the latter part of the same year came Shamburg. In 1868, the Pleasantville oil-field furnished the principal centre of excitement."

Meanwhile, in West Virginia, in Ohio, and in Southern Kentucky, oil-fields were developed. In 1860, an old brine well at Burning Springs, West Virginia, that had yielded petroleum, was cleaned out, and tubed, and a yield of fifty barrels per day secured. Another well drilled shortly afterwards to a depth of only 100 feet, flowed as much as 1000 barrels per day. In 1864 and 1865, a number of deeper wells were drilled and a considerable quantity of oil was obtained.

From 1870 to 1880, the region between Tidioute and Oil Creek gradually became of smaller importance in relation to the entire producing territory in Pennsylvania. Wells had previously been drilled near the junction of the Clarion and Allegheny rivers, and in 1868 a successful well on the hill above Parker's Landing led to the development of what is termed the "lower country," lying in Butler, Armstrong, and Clarion counties. In the meantime, other operators prospecting in a north-east direction from the "upper country" of Oil Creek, found oil in the neighbourhood of Bradford, in McKean County, and thus commenced the development of the enormously productive Bradford field. In December 1878, four years after the drilling of the first successful well in the Bradford territory, the production of oil in that district amounted to a daily average of 23,700 barrels, or about four-sevenths of the total daily production of the State of Pennsylvania, and two years later the Bradford field produced 63,000 barrels out of a total of 72,215 barrels. In a paper read at a meeting of the American Institute of Mining Engineers, in September 1885, Mr. Ashburner, geologist in charge of the Pennsylvania Survey, classified the producing territory in the States of Pennsylvania and New York into the following six principal districts:

1. Allegheny district, including Richburg, with an area of twenty-eight square miles, and several small outlying pools in Allegheny County, bringing up the total area to thirty-one square miles.

2. Bradford district, embracing the oil-pools in central and southern McKean County, Pa., and southern Cattaraugus County, New York, with an area of 133 square miles, 121 square miles of which are included in the Bradford field proper.

3. Warren district, comprising the oil-pools in eastern Warren County, and north-eastern Forest County, Pa., with a total area of thirty-five square miles, the two largest pools being the Clarendon in Warren County, with an area of fourteen square miles, and the Cooper and Sheffield, partly in Warren and partly in Forest, covering an area of nine square miles.

4. Venango district, with an area of sixty-four square miles, including forty distinct and well-recognised pools, the largest being that which lies between Oil City on the south and Pleasantville on the north, covering an area of twenty-eight square miles.

5. Butler district, including the oil-pools in Butler and Clarion Counties and south-eastern Venango County, the total area being eighty-four square miles, of which seventy-six are embraced in the Clarion, Butler and Armstrong fields, and the Butler cross-belt.

6. Beaver district, including the two principal oil-pools known as Slippery Rock and Smith's Ferry. The former pool, and that portion of the latter east of the Pennsylvania State line, cover an area of about sixteen square miles.

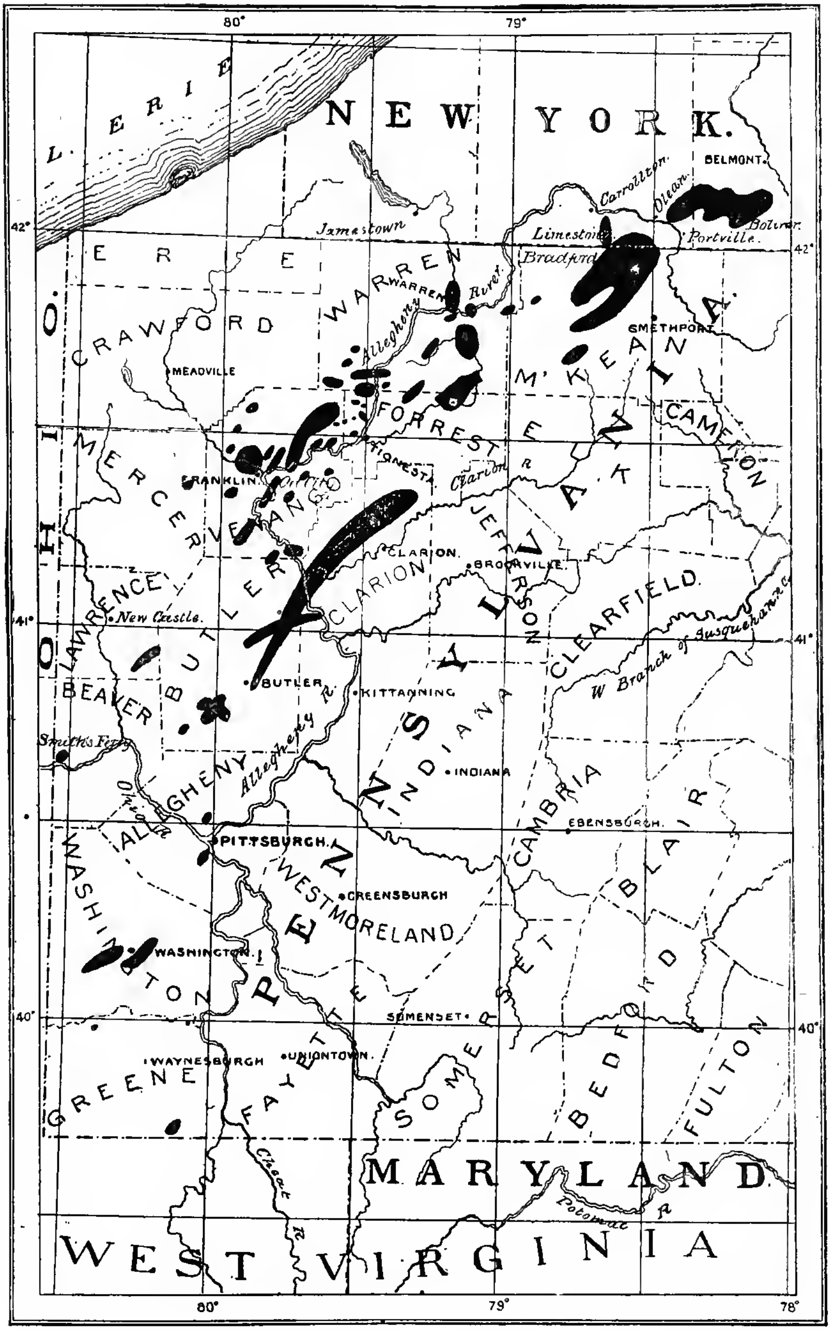
Mr. Ashburner added that outside these limits a small amount of oil had been found in isolated pools at the south and south-east of the Beaver and Butler districts; at Mount Nebo in the vicinity of Pittsburg; in the neighbourhood of Pleasant Unity, Westmoreland County; near the mouth of Dunlap Creek in Fayette County; along Whiteley Creek, west of Mapletown, and along Dunkard Creek, north of Fairview, both in Green County, and in the vicinity of Washington, Washington County. The "small amount" of oil found in the last-mentioned locality was not at first considered to be an indication of much promise, but the principal feature of interest in the production of petroleum in Pennsylvania during the year 1886 was, nevertheless, the rapid development of the Washington field. In December 1884 a well was drilled on the Gantz farm, near Washington (Washington County), by the Citizens' Fuel Company, for the purpose of obtaining natural gas to be used as fuel. At a depth of 2200 feet, oil, and not gas, was obtained, but the yield was not considerable. In August 1885, the famous Gordon flowing well was completed, and renewed attention was directed to the field. In March 1886, the Pew and Emerson "Manifold" well, and in the following month the Thayer well, the latter flowing 2000 barrels per day, afforded indisputable evidence of the richness of the field, and during the month of August the production reached its maximum of about 16,000 barrels per day. After that period the production steadily declined, and for the year 1887 was only 4800 barrels per day.*

The oil-belt running through the principal producing territories named lies on a line extending in a north-easterly and south-westerly direction, this line being termed the 45° line. See Map (Fig. 71).

The chief event of recent years in the history of the petroleum industry of the United States has been the remarkable development of the Ohio oil-

* A few miles due north of the Washington field, and on the borders of Washington and Allegheny Counties, lies the recently developed McDonald field, the very productive character of which has attracted so much attention. This field, with an area of not more than 2000 acres, was producing in October 1891 between 50,000 and 60,000 barrels of oil a day. One well yielded as much as 15,000 barrels a day.

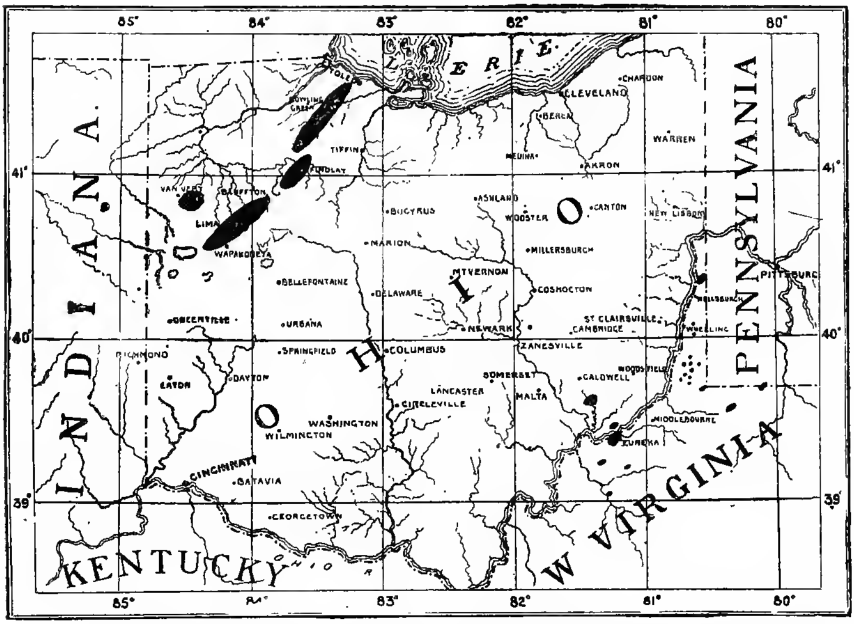
FIG. 71.


L. ERIE
NEW YORK.
BELMONT.
Carrollton.
Olean.
Bolivar.
Portville.
Jamestown
Limestone
Bradford
ERIE
WARREN
WARREN
Allegheny River
CRAWFORD
MEADVILLE
M'KEAN
SMETHPORT
CAMERON
FORREST
TIONESTA
Clarion R
MERCER
FRANKLIN
VENANGO
JEFFERSON
CLARION
CLARION
BROOKVILLE
LAWRENCE
New Castle
BUTLER
BUTLER
CLEARFIELD
W Branch of Susquehanna
OHIO
BEAVER
KITTANNING
Allegheny R
Smith's Ferry
ALLEGHENY
INDIANA
INDIANA
CAMBRIA
EBENSBURGH
Ohio R
PITTSBURGH
PENNSYLVANIA
WESTMORELAND
GREENSBURGH
BLAIR
WASHINGTON
WASHINGTON
SOMERSET
BEDFORD
FULTON
WAYNESBURGH
UNIONTOWN
GREENE
FAYETTE
Cheat R
MARYLAND
Potomac R
WEST VIRGINIA
80°
79°
78°
42°
41°
40°

fields. Prior to 1885, the production of that State was not very large, though it had been growing steadily during the previous ten years, but in 1885 the drilling of wells proceeded with great activity and the yield has increased to enormous proportions. Petroleum is found both in the eastern and in the western portions of Ohio, but it is in what is known as the Lima district in the north-western part of the State (see Map, Fig. 72), that the principal production occurs. This oil unfortunately contains sulphur compounds which are extremely difficult of removal, and it is therefore not a satisfactory source of kerosene, but it appears to be well adapted for use as liquid fuel, and is very largely employed for that purpose.

In West Virginia, a heavy description of petroleum, extensively employed as a lubricant, has long been obtained, but during recent years lighter oils, yielding kerosene, have also been found.

FIG. 72.



Kentucky and Tennessee have for some time past been included among the petroleum-yielding States, though the quantity hitherto obtained has been small; and in Colorado there is now a production which exhibits promising growth. Indiana, Illinois, Kansas, and Texas have also commenced to contribute to the total production.

Petroleum has been met with in many localities along the coast range of mountains in Southern California, but Ventura, Los Angeles, and Santa Barbara appear to be the most productive counties. The oldest wells are situated in Pico Cañon, San Fernando Mountain, about six miles west of Newhall in Los Angeles County. The existence of oil in this cañon is said to have been known to one Andreas Pico for some years prior to 1857, but no drilling appears to have been done there until 1869, when the Pico well was drilled. The active development of the field was commenced in 1875, and the area defined when the writer visited the cañon in the autumn of 1886 was about two miles by a quarter of a mile. At this period there were sixteen wells, daily producing in the aggregate about 500 barrels of forty-

two American gallons. None of the wells drilled since 1875 had become exhausted, the least productive of the wells yielding from five to seven barrels per day, while one (a flowing well drilled four or five years previously) was stated to furnish as much as forty barrels daily; with the exception of this one, all the wells were pumped. The earlier attempts to obtain petroleum in this district had been made by driving tunnels into the mountain, and from one of these tunnels oil was flowing in small quantity at the time of the writer's visit. The various deposits have been described with much minuteness by Professor Hanks, formerly mineralogist to the State of California, in his fourth annual report (dated 1884) to the State Mining Bureau.

The Governor of Wyoming stated in 1885, in his annual report to the Secretary of the Interior, that extensive oil-basins were situated in that territory east of the Wind River and north of the Rattlesnake range of mountains, the principal deposits being apparently located in Fort Washakie, Lander, Shoshone, Beaver Creek, Big Horn, Rattlesnake, Seminole, and Laramie ranges.

The following statistical details relating to the petroleum industry in the United States are from a Census bulletin prepared by Mr. Jos. D. Weeks, special agent in charge of statistics relating to petroleum and natural gas, under the supervision of Dr. David S. Way, special agent in charge of the Division of Mines and Mining of the Census Office, and issued by the Department of the Interior, Washington, D.C., May 16, 1891. The statistics show that petroleum was produced in eleven States in 1889—viz., Pennsylvania, New York, Ohio, West Virginia, Colorado, California, Indiana, Kentucky, Illinois, Kansas, and Texas The total production was 34,820,306 barrels (of 42 American gallons) valued at $26,554,052. Of the total production, 109,891 barrels were disposed of for lubricating purposes (only natural lubricating oils, however, being included under this head), 12,330,813 for fuel, and 22,379,602 for illuminating purposes. Nearly the entire amount produced in California, Indiana, and Ohio was used for fuel, while nearly the entire amount produced in Colorado, New York, Pennsylvania, and West Virginia was used for illuminating purposes.

Production of Crude Petroleum in the United States in 1889, by States.

	Barrels of 42 American Gallons.
Pennsylvania and New York*	21,486,403
Ohio	12,471,965
West Virginia	358,269
Colorado	316,476
California	147,027
Indiana	32,758
Kentucky	5,400
Illinois	1,460
Kansas	500
Texas	48
	34,820,306

* In this statement the production of Pennsylvania and that of New York are united. The Bradford (Pennsylvania) and Allegheny (New York) fields are regarded as one in petroleum reports. Of the 21,486,403 barrels produced in Pennsylvania and New York in 1889, 7,158,362 barrels were produced in these two districts. The Bradford district lies partly in Pennsylvania and partly in New York. The collection and shipment of its product by pipe lines are so conducted that it is almost impossible to determine the respective quantities produced in the two States.

Production of Crude Petroleum for 1889, Classified according to Uses.

States or Districts.	In Barrels of 42 American gallons.			
	Illuminating.	Lubricating.*	Fuel.	Total.
Pennsylvania and New York	21,393,160	93,243	—	21,486,403
Ohio	317,037	1,740	12,153,188	12,471,965
West Virginia	345,369	12,900	—	358,269
Colorado	316,476	—	—	316,476
California	2,160	—	144,867	147,027
Indiana	—	—	32,758	32,758
Kentucky	5,400	—	—	5,400
Illinois	—	1,460	—	1,460
Kansas	—	500	—	500
Texas	—	48	—	48
	22,379,602	109,891	12,330,813	34,820,306

Value of Petroleum produced in 1889.—The following table shows the value of the different kinds of petroleum produced in the Census year, by the several States, and the total value of the petroleum produced in the United States:

Value of the Crude Petroleum produced, according to Uses.

States or Districts.	For Illuminating.	For Lubricating.	For Fuel.	Total Value.
Pennsylvania and New York	23,225,460	267,989	—	23,493,449
Ohio	340,683	10,558	1,822,978	2,174,219
West Virginia	344,868	34,775	—	379,643
Colorado	278,240	—	—	278,240
California	7,600	—	186,462	194,062
Indiana	—	—	21,293	21,293
Kentucky	5,400	—	—	5,400
Illinois	—	4,906	—	4,906
Kansas	—	2,500	—	2,500
Texas	—	340	—	340
Total	$24,202,251	$321,068	$2,030,733	$26,554,052

Production by States.—In the following table is given the total production of crude petroleum in the United States in 1889, by States and Districts.

Production of Crude Petroleum in 1889, by States and Districts.

States and Districts.	Barrels of 42 American Gallons.	
Pennsylvania and New York:		
Bradford District, Pennsylvania, and Allegheny County, New York	7,158,363	
Forest County	258,955	
Warren County	2,347,434	
Butler and Clarion Counties, &c.	5,358,403	
Tidioute and Titusville	885,119	
Allegheny County	541,092	
Beaver County	602,736	
Washington County	3,848,145	
Greene County	392,912	
Franklin District	64,244	
Smith's Ferry District	29,000	
		21,486,403
Ohio:		
Lima	12,153,188	
Macksburg	317,037	
Mecca and Belden	1,740	
		12,471,965

* Only natural lubricating oils included under this head.

States and Districts.		Barrels of 42 American Gallons.
Brought forward		33,958,368
West Virginia:		
Southwest	284,269	
Volcano	71,500	
Burning Springs	2,500	
		358,269
Colorado		316,476
California		147,027
Indiana		32,758
Kentucky		5,400
Illinois		1,460
Kansas		500
Texas		48
Total		34,820,306

In the table on p. 108 will be found consolidated the statistics of the production of petroleum in the various States of the United States from the beginning of operations in these fields, so far as the same could be ascertained.

The stocks of crude petroleum on December 31, 1888 and 1889, were as follows:

States.	Barrels of 42 American Gallons.	
	Dec. 31, 1888.	Dec. 31, 1889.
Pennsylvania and New York	18,995,814	11,562,594
Ohio	10,161,842	14,415,997
Colorado	13,092	36,034
Kansas	240	150
Illinois	110	100
Texas	6	48

Exports of Oil.—The following table shows the number of American gallons of petroleum and petroleum products exported in the years 1888, 1889, and 1890.

	1888.	1889.	1890.
Crude	77,387,796	83,991,196	95,365,765
Naphtha	13,466,234	13,958,680	12,406,586
Illuminating	451,964,143	548,395,731	547,542,569
Lubricating	24,280,826	27,754,239	31,886,146
Residuum	1,861,104	1,838,694	1,828,900
Total	568,960,103	675,938,540	689,029,966
Value	$47,649,345	$52,793,241	$51,656,677

The drilling of a gas well at Fredonia, Chatauqua County, N.Y., in 1821, has already been mentioned. In 1858, another well was drilled in this locality, which supplied 200 burners, and in 1871 a still larger well was drilled to a depth of 1200 feet. Mr. E. J. Crissey, secretary of the Fredonia Natural Gas Light Company, states that the average monthly yield of these wells in 1880 was 110,000 cubic feet. For many years past systematic drilling for gas has taken place, and immense quantities have been employed as fuel—notably in Pittsburg (see Chemical Technology, vol. i., "Fuel," p. 286 *et seq.*). The natural gas companies have, however, found it impossible to obtain adequate supplies, and many manufacturers have had to revert to the use of other fuel.

Product of Crude Petroleum in the United States from 1859 to 1889.(a)

Years.	Barrels of 42 American Gallons.										
	Pennsylvania and New York.	Ohio.	West Virginia.	Colorado.	California.	Indiana.	Kentucky and Tennessee.	Illinois.	Kansas.	Texas.	Total, United States.
1859	2,000	—	—	—	—	—	—	—	—	—	2,000
1860	500,000	—	—	—	—	—	—	—	—	—	500,000
1861	2,113,609	—	—	—	—	—	—	—	—	—	2,113,609
1862 (b)	3,056,690	—	—	—	—	—	—	—	—	—	3,056,690
1863	2,611,309	—	—	—	—	—	—	—	—	—	2,611,309
1864	2,116,109	—	—	—	—	—	—	—	—	—	2,116,109
1865	2 497,700	—	—	—	—	—	—	—	—	—	2,497,700
1866	3,597,700	—	—	—	—	—	—	—	—	—	3,597,700
1867	3,347,300	—	—	—	—	—	—	—	—	—	3,347,300
1868	3,646,117	—	—	—	—	—	—	—	—	—	3,646,117
1869	4,215,000	—	—	—	—	—	—	—	—	—	4,215,000
1870	5,260,745	—	—	—	—	—	—	—	—	—	5,260,745
1871	5,205,234	—	—	—	—	—	—	—	—	—	5,205 234
1872	6,293,194	—	—	—	—	—	—	—	—	—	6,293,194
1873	9 893,786	—	—	—	—	—	—	—	—	—	9,893,786
1874	10 926,945	—	—	—	—	—	—	—	—	—	10,926,945
1875	8,787,514	c 200,000	c 3,000,000	—	c 175 000	—	—	—	—	—	12,162,514
1876	8 968,906	31,763	120,000	—	12,000	—	—	—	—	—	9,132 669
1877	13,135,475	29,888	172,000	—	13,000	—	—	—	—	—	13,350 363
1878	15,163,462	38,179	180,000	—	15,227	—	—	—	—	—	15,396,868
1879	19,685,176	29,112	180,000	—	19,858	—	—	—	—	—	19,914,146
1880	26 027,631	38,940	179,000	—	40,552	—	—	—	—	—	26,286 123
1881	27,376,509	33,867	151,000	—	99 862	—	—	—	—	—	27,661,238
1882	30,053,500	39,761	128,000	—	128,636	—	d 160,933	—	—	—	d30,510,830
1883	23,128 389	47,632	126 000	—	142 857	—	4,755	—	—	—	23,449,633
1884	23,772,209	90,081	90 000	—	262,000	—	4 148	—	—	—	24,218,438
1885	20,776,041	650,000	91,000	—	325,000	—	5,164	—	—	—	21,847 205
1886	25,798,000	1,782,970	102 000	—	377,145	—	4,726	—	—	—	d28,064,841
1887	22,356,193	5,018,015	145,000	76,295	678,572	—	4,791	—	—	—	28,278 866
1888	16,484,668	10,010,868	119,448	297,612	690 333	—	5,096	—	—	—	27,608,025
1889	21,486,403	12,471,965	358,269	316,476	147,027	32,758	5,400	1,460	500	48	34,820,306
Total	368,283,514	30,513,041	5,141,717	690,383	3,127,069	32,758	195,013	1,460	500	48	407,985,503

a. Some oil was produced in other States, but no record has been secured other than that contained in note *b*.

b. In addition to the above, it is estimated that for want of a market some 10,000,000 barrels ran to waste in and prior to 1862 from the Pennsylvania fields; also a large amount from West Virginia and Tennessee.

c. Including all production prior to 1876.

d. This includes all the petroleum produced in Kentucky and Tennessee prior to 1883.

NOTE.—Mr. Weeks has very courteously informed the writer that considerable difficulty was experienced in obtaining accurate information respecting the production in California. The figures given for 1889 were based upon such particulars as had been received up to the date of publication of the bulletin, but were regarded as an understatement of the quantity. On the other hand, there appears to be reason to believe that the estimates of production in previous years were exaggerated. In the opinion of Mr. Weeke the production in California during the years 1889–1890 probably amounted to about 325,000 barrels per annum.

III. Historical Account of the Development of the Petroleum Industry in Russia.

Upon the annexation of Baku by Russia, in 1801, the monopoly of the production of petroleum was granted by the Government to a refiner named Meerzoeff. This arrangement lasted until 1872, when the monopoly was abolished and an excise duty upon all petroleum raised was imposed. According to the late Mr. Marvin, from 1821 to 1825, Meerzoeff paid the Government 131,000 roubles revenue, and afterwards, up to 1839, from 76,000 to 97,000 roubles a year, or, at the rate of the silver rouble then prevailing (ranging between six and seven roubles to the pound sterling), on an average about £10,000 to £12,000 sterling. During this period the production of crude petroleum rose steadily to more than a million gallons. The output from 1832 to 1849 (when there were about 140 pit-wells in operation), was as follows:

	Poods.*		Poods.		Poods.
1832	261,000	1838	340,554	1844	328,280
1833	300,000	1839	358,357	1845	327,167
1834	346,109	1840	337,010	1846	332,854
1835	352,720	1841	326,695	1847	316,850
1836	352,862	1842	329,578	1848	288,112
1837	344,147	1843	327,802	1849	255,476

Between 1850 and 1863, petroleum yielded a revenue of 1,195,000 roubles. From the latter year to 1867 the average revenue yearly was 162,000 roubles; and afterwards, until the abolition of the monopoly and substitution of an excise duty in 1872, 136,000 roubles. The production in the meantime was as follows:

	Poods.		Poods.		Poods.
1863	340,000	1867	998,905	1870	1,704,465
1864	538,966	1868	735,764	1871	1,375,523
1865	554,291	1869	1,685,229	1872	1,537,600
1866	691,820				

In 1872, the number of pit-wells had been increased to 415, and two wells had been drilled.

After the abolition of the monopoly, Meerzoeff for a time maintained his supremacy in the trade, but, in 1873, the Khalify Company struck a flowing well, and thus obtained the largest supply of the crude material; and a year later the Transcaspian Trading Company took the lead in the business. In 1875, the late Mr. Ludwig Nobel and his brother Robert inaugurated a new era in the Russian petroleum business, by the introduction of improved appliances for producing, transporting, and refining the oil.

During the excise duty period, the output of crude petroleum was as follows:

	Poods.		Poods.		Poods.
1873	3,968,000	1875	5,828,000	1877	12,000,000
1874	4,836,000	1876	12,028,000		

At the end of this period, the number of drilled wells had been increased to 130.

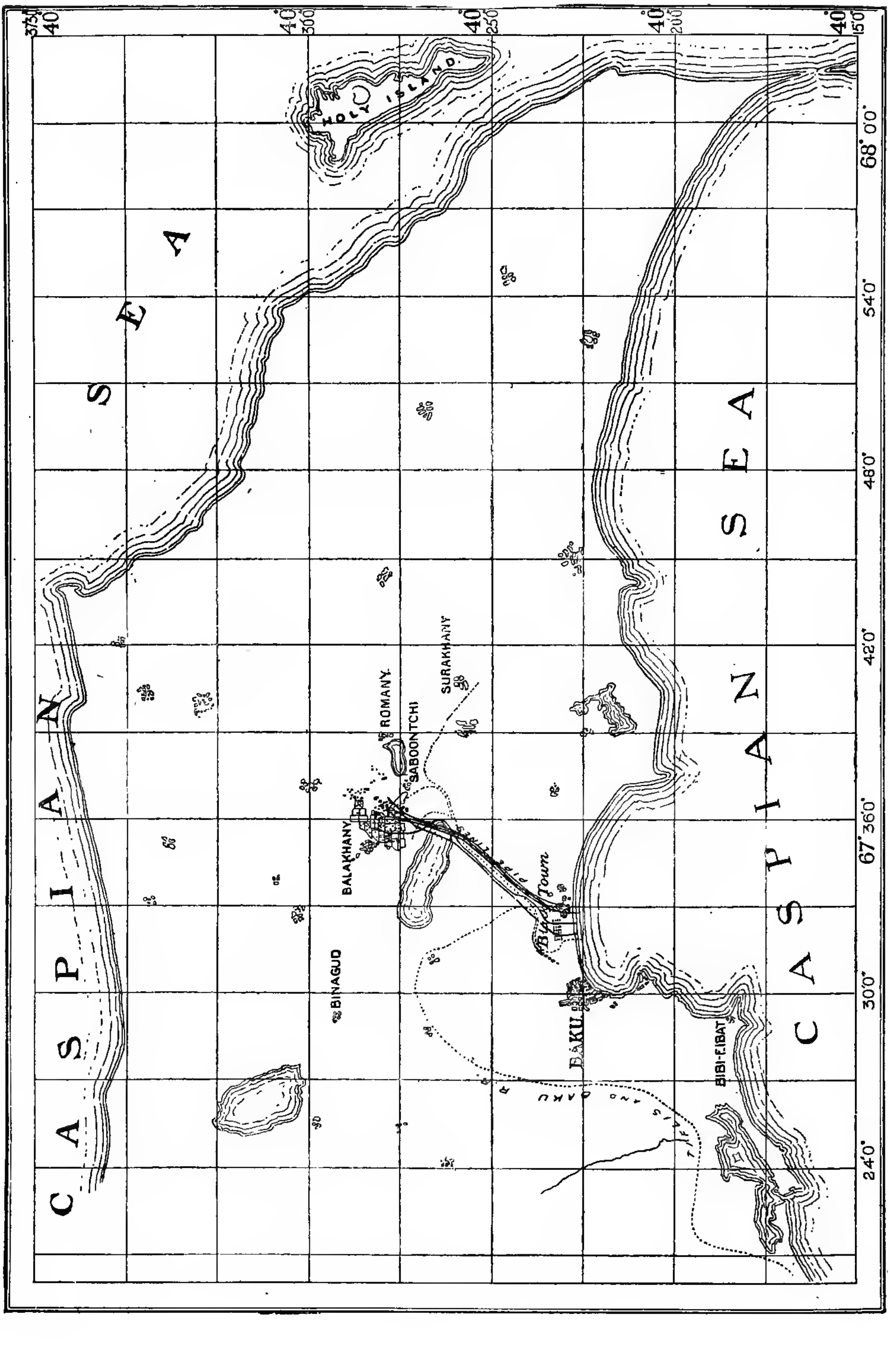
In 1877, the excise duty was removed, and from that time the production of crude petroleum has, according to the official statistics, been as follows:

	Poods.		Poods.		Poods.
1878	15,000,000	1883	60,000,000	1887	165,000,000
1879	21,000,000	1884	90,000,000	1888	192,600,000
1880	25,000,000	1885	116,000,000	1889	205,500,000
1881	40,000,000	1886	150,000,000	1890	239,000,000†
1882	50,000,000				

* 1 Pood = 36.1127 lbs. av.

† Of this amount more than $18\frac{1}{4}$ million poods were produced in the Bibi-Eibat field (see Map, Fig. 73), and more than $1\frac{1}{2}$ million poods in the Romany field (see Map Fig. 73), the remainder being the produce of the Balakhany-Saboontchi field.

Fig. 73.


CASPIAN SEA
CASPIAN SEA
HOLY ISLAND
ROMANY
SABOONTCHI
SURAKHANY
BALAKHANY
BINAGUD
Black Town
BAKU
BIBI-EIBAT
68° 0'0
54'0
48'0
42'0
67° 36'0
30'0
24'0

When the writer visited Baku in the autumn of 1884, there were about 400 drilled wells in the district, of which only about 100 were, however, yielding oil. At the end of the year 1889 there were 261 producing wells.

The Balakhany and Saboontchi oil-fields (see Map, Fig. 73), which are classed together, have an area of about four square miles, and lie at an elevation of 175 feet above sea-level, about eight miles north-east of the town of Baku. A number of wells have also been successfully drilled in the neighbouring districts of Romany and Binagudi; and in the Bibi-Eibat field, two or three miles south of Baku, some of the most productive wells have been drilled. Petroleum also occurs at Surakhany, about eleven miles north-east of Baku. The positions of these districts are shown on the map of the Apsheron peninsula, Fig. 73. In many localities between Baku and Batoum, petroleum is met with, and in the Northern Caucasus there has been a steadily growing production for several years past.* To the southward of Baku petroleum gas rises through the sea, and in Holy Island, off the north-eastern coast of the peninsula, oil-springs occur. Petroleum is also found on the Transcaspian mainland, as well as on the island of Tcheleken.

The Kouban oil-fields, 47 miles in a direct line inland from the port of Novorossisk on the Black Sea, have been known for many years, and the crude petroleum had long been used by the Cossacks as cart-grease before Colonel Novosiltsoff, who had been granted the monopoly of the Kouban petroleum industry, commenced drilling for oil at Illsky. During the years 1873 to 1875 nine wells were completed in this district, but the yield of petroleum was comparatively small, and Colonel Novosiltsoff shortly afterwards found himself in financial difficulties. In 1879, a lease of the greater part of the property was granted to Dr. Tweddle, whose rights were subsequently acquired by the Standard Russe Petroleum Company of Marseilles. Up to 1886, 69 wells had been drilled at Illsky, all but one of which are stated to have yielded oil; and when Colonel C. E. Stewart visited the field in the autumn of that year, fifteen of these were producing. North of Illsky lies the petroleum field of Koudako, where Colonel Novosiltsoff conducted some experimental drilling in 1866. This property is now owned by General Dourassoff. Ten wells have been drilled here, and four are said to yield oil. One of the first wells completed is stated to have spouted with violence, and to have thrown up a very large quantity of oil for a short time.

A large number of wells have been drilled in the neighbourhood of Kertch, but seem to have produced but little oil.

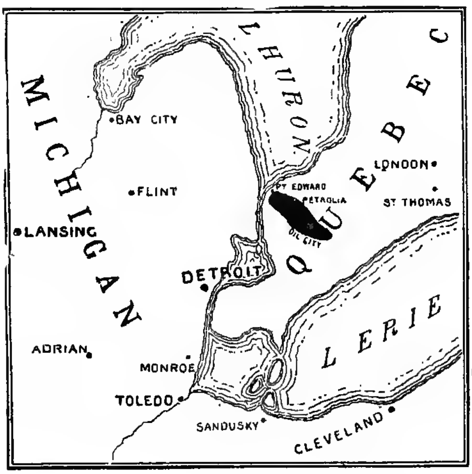
IV. Historical Account of the Development of the Petroleum Industry in Canada.

The development of the oil territory of Canada dates from 1857, when a well dug for water was found to yield a quantity of petroleum, but it is stated in Henry's "Early and Later History of Petroleum" that from the time of the earliest settlements in the county of Lamberton, in the western part of the province of Ontario: "A dark oily substance had been observed floating on the surface of the water in the creeks and swamps. No matter how deep the wells were dug, the water was brackish and ill-smelling, and in some localities totally unfit for use; while a surface of black oily slime frequently arose, an inch thick, as cream rises on milk. Here and there in the forests the ground consisted of a gummy, odoriferous, tar-coloured mud, of the consistence of putty. These places were known by the name of gum-beds, and in two or three instances were of considerable extent."

* In the Gouria district, north of Batoum there are promising indications of petroleum which are attracting attention.

In 1862, flowing wells of remarkably productive character were struck at Oil Springs, but the wells, which were of comparatively little depth, quickly became exhausted, and in 1865 the discovery of oil at Petrolia, seven miles to the northward, and about sixteen miles south-east of the outlet of Lake Huron, caused the Oil Springs territory to be deserted. A few years later, however, the wells at Oil Springs were drilled deeper, and at the end of the year 1886 were producing 10,000 to 12,000 barrels (of 42 American gallons) per month. Petroleum has also been found at Bothwell, thirty-five miles from Oil Springs, and after this district ceased to yield, a new territory was discovered at Euphemia, seventeen miles from Bothwell. Here, at the time of the writer's visit to Ontario in the autumn of 1886, there were four wells, producing collectively 70 barrels per day. The producing oil-belt may thus be said to have extended from Petrolia, in a north-westerly direction to the township of Sarnia, and in a south-easterly direction to Oil Springs, but in the latter direction the extension was apparently not continuous. The geographical position of the territory will be seen on reference to the Map (Fig. 74). In all, about 15,000 wells were estimated to have been drilled in the Canadian oil-fields up to the time of the writer's visit, and of these about 2500 were producing, the average yield being about three-quarters of a barrel per well per day. The aggregate production is about 700,000 barrels per annum, the greater part of which is obtained from the Petrolia district.

FIG. 74.

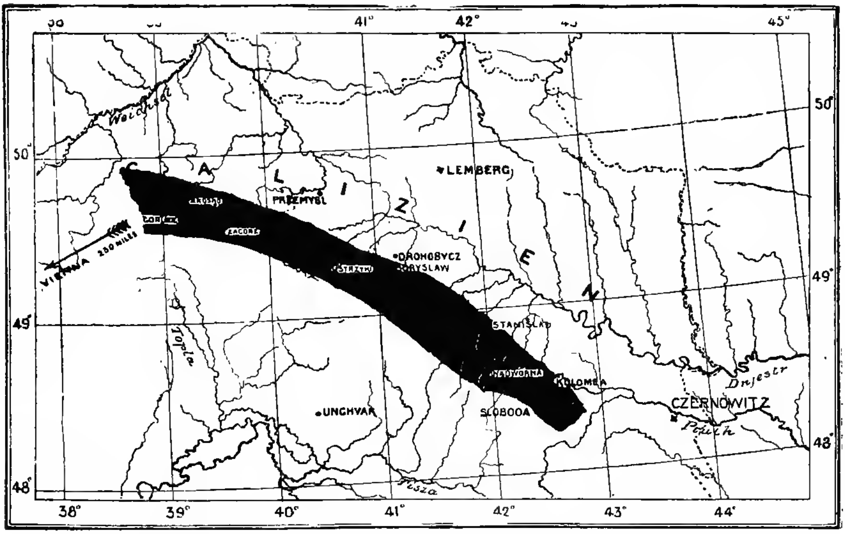


V. The Galician Petroleum Industry.

The discovery of petroleum near Kolomea, in what is now the Sloboda-Rungurska oil-field, was made, as has been stated, in 1771, when a well drilled for brine was found to yield petroleum in small quantity. This historic well was deepened in 1859 and 1865 by digging, and in 1875 and 1884 by drilling; the yield being thus finally increased to ten barrels a day. In 1881, the active development of the district commenced, and in 1883 the field was reported to be yielding 550 barrels of crude oil per day within an area 1500 metres in length, and 350 to 500 metres in breadth. The Sloboda-Rungurska field was for a time the most productive of the Galician oil territories, the production at one period having increased to over 1600 barrels per day, but when the writer visited the field in the autumn of 1887 the yield had decreased to about 800 barrels per day, notwithstanding that considerable activity was still displayed in the drilling of new wells. Previously to the decline in the production of the Sloboda-Rungurska field, attention had been directed to the development of the deposits in central and western portions of the belt of petroliferous territory, and many highly productive oil-fields have thus been established. Not far from the western end lies the Bobrka district, where the petroleum

industry of Galicia may be said to have had its birth, for it was from this locality that the crude petroleum was obtained which was successfully refined by Lucasiewicz in or prior to the year 1854. On the Bobrka field, a stone obelisk has been erected by Messrs. Klobassa and Tszecieske, the owners of the property, bearing an inscription of which the following is a translation :—" To commemorate the founding of the petroleum mine in Bobrka in the year 1854 by Ignacy Lukasiewicz. 4th November, 1872." The area within which the principal petroleum deposits of Galicia are believed to lie has a length of about 220 miles, and a breadth of from 40 to 60 miies, the "belt" running in a general south-easterly and north-westerly direction, as shown in the Map (Fig. 75).

FIG. 75.



In the following table the quantities of crude petroleum produced in and imported into the kingdom of Austria-Hungary during the years 1883–90 are given. The figures are from official sources, but the production is believed to be largely understated.

Year.	Production of Austria-Hungary.	Imported into Austria-Hungary.	Consumption.
	Barrels.	Barrels.	Barrels.
1883	166,500	735,060	901,560
1884	233,000	899,735	1,132,735
1885	333,000	937,345	1,270,345
1886	433,000	858,976	1,291,976
1887	532,000	388,110	920,110
1888	665.000	801,715	1,466,715
1889	746,000	930.191	1,676,191
1890	816,000	867.831	1,683,831

The principal seat of the ozokerite mining industry is at Boryslaw, but the material has also been mined to a small extent at Dwiniacz and Starunia, which lie to the south of Stanislaw. The industry has existed for the past thirty years, and the annual production of ozokerite in Austria-Hungary during the past fourteen years according to official records has been as follows, but it is well known that the actual output has been greatly in excess of the figures given :—

Year.	Metre-Centners of 100 kilos.	Year.	Metre-Centners of 100 kilos.
1877	89,610	1884	119,669
1878	103,420	1885	130,258
1879	90,666	1886	139,254
1880	105,270	1887	80.500
1881	106,491	1888	87,800
1882	99,300	1889	75,600
1883	106,299	1890	61,699

VI. General Geographical Account of Petroleum, and Detailed References to Petroleum Deposits of Minor Importance.

Professor Peckham* states that petroleum, in a solid, liquid or gaseous form, occurs :—

"On the American continent along a line extending from Point Gaspé, in Canada, to Nashville, Tennessee, and in Europe-Asia along a line extending from Hanover, on the North Sea, through Galicia, the Caucasus and the Punjab. These are the principal lines. In America it also occurs on the Pacific coast, from the Bay of San Francisco to San Diego; again, from Northern Nebraska to the mouth of the Sabine River, on the Gulf of Mexico; again, from Havana, near the western end of Cuba, through San Domingo, and the circle of the Windward and Leeward Islands, to Trinidad; thence westward on the mainland to the Magdalena River, and southward from that point to Cape Blanko, in Peru. In Europe-Asia, bitumen occurs on the lower Rhine, and in the valley of the Rhone; from Northern Italy, following the Apennines, to Southern Sicily; along the eastern shores of the Adriatic, through Dalmatia and Albania, into Epirus; again, along the depression in which lie the Jordan and the Dead Sea; again, along the mountains that border the valley of the Tigris in the east; again, from Western China, through Burmah, Pegu, Assam, Sumatra and Java; and lastly, in Japan. It will be observed that these lines are, for the most part, intimately connected with the principal mountain chains of the world."

Of the European deposits of petroleum, by far the most important are those in Russia, of which a detailed description has already been given in the historical account of the Russian petroleum industry. Next in order of importance come the Galician deposits, which have also been described. The Roumanian petroleum deposits, which are situated in North-east Wallachia and in Southern Moldavia, have attracted less attention than the Galician deposits, but are nevertheless of considerable potential importance, though the production has not hitherto been large. Petroleum also occurs in the Bukowina, Transylvania and Hungary, as well as in Dalmatia and Albania.

In Germany, petroleum has been obtained commercially for some years past at Oelheim, and at Wietze-Steinförde, in the neighbourhood of Hanover. Latterly a considerable amount of drilling has been done in Elsass, where petroleum has long been known to occur at Schwabweiler, Pechelbronn and Lobsan, and a productive oil territory has been opened up. Petroleum is also met with along the Eastern Vosges, and on the shores of the Tegernsee.

In Northern Italy there is a petroliferous territory extending from the south of Milan to the south of Bologna, and in the district which lies immediately south of Piacenza productive wells exist. The petroleum found at Miano has already been referred to in the general history of petroleum. In Southern Italy and in Sicily the oil is also met with.

* Census Report on the Production, Technology, and Uses of Petroleum. Washington, 1884.

In France, indications of petroleum occur near Clermont and Grenoble, as well as in the Basses Pyrénées.

In Spain, petroleum has been found near Burgos, and is also stated to occur near Seville.

Wells have been drilled in the island of Zante near the historic "pitch spring," referred to in the general history of petroleum as having been mentioned by Herodotus, but petroleum has not been obtained hitherto in this locality in sufficient quantity to render the enterprise profitable; the wells have, however, not been carried to any great depth, and the oil-bearing character of the strata has, therefore, probably not been sufficiently tested.

The occurrence of petroleum in a coal-mine in Derbyshire has already been referred to. The oil has also been found in the coal-measures in Shropshire, Lancashire, Staffordshire, and elsewhere; in a shale mine at Broxburn, Linlithgowshire; in limestone, near Bristol; and in a peat bog at Down Holland, near Ormskirk. The indications of petroleum at Down Holland were thus described by Messrs. Binney and Talbot in a paper read before the Manchester Geological Society in 1843:

"The whole of the moss is in cultivation, either under the plough or in grass, and has been so for at least forty or fifty years, and all, or the greater portion of it, lies at a lower level than the high-water mark of the sea at Formby. On approaching the place where the peat containing the petroleum occurs, from Down Holland, the authors soon became aware of its presence by an empyreumatic smell, resembling that yielded by Persian naphtha, and the water in the ditches was also coated with a thin film of an oily iridescent fluid that floated upon its surface. In walking over some oat stubble fields, and thrusting their heels through the black decomposed peat forming the soil, they felt a hard pitchy mass of three or four inches in thickness, which yields no smell unless it is burned. On exposure to the atmosphere for a time, the pitchy matter lost the greater part of its inflammability, and was finally converted into black mould. This substance also occurred under the roots of the grass in old sward fields, but it then yielded an odour similar to the petroleum that floated on the surface of the water, and pervaded the moist peat."

In Asia, petroleum occurs in Asia Minor, in Persia, in Upper and Lower Burmah (including the Arakan islands), in Assam, in the Punjab, and in Baluchistan, in Siam, in China and in Japan, as well as in the islands of the Indian Archipelago.

The oil-fields of Twingaung and Beme, from which the so-called Rangoon oil was originally obtained, are situated in Upper Burmah about a mile and a half to the east of Yenangyoung on the river Irrawaddy. From a report by Dr. Fritz Noetling, Palæontologist, Geological Survey of India,* it appears that the fields are of the respective areas of ninety acres and thirty-five acres, and are about half a mile apart. In the Twingaung field, in April 1888, there were 375 wells, of which 166 were wholly unproductive, and of the remainder only 120 produced more than 20 viss per day (1 viss = 3.67 lbs. avoirdupois). The maximum yield of a single well was 500 viss per day, and the majority of the wells produced from 20 to 100 viss per day. The total daily production of this field was 12,000 viss. At the same date there were 151 wells in the Beme field, of which 79 were wholly unproductive, and of the remainder only 50 produced more than 20 viss per diem. The maximum production of a single well was not more than 165 viss, and the total daily production of the field was 3658 viss. All the wells were sunk by the primitive method of digging adopted by the

* Report on the Oil Fields of Twingaung and Beme, with a Map and a Plan of Geological Sections. Rangoon, June 1889.

Burmese. The maximum depth of the wells in the Twingaung field did not exceed 310 feet, and in the Beme field 270 feet, but the majority of the wells in both fields were still more shallow. In the oil-field of Kodoung, which lies between Twingaung and Beme (see Sketch Maps of Oil Fields of India, No. IV., Plate), a considerable number of wells have been drilled with modern appliances, and some of these have yielded largely. Petroleum also occurs in Upper Burmah, north of Pagan, on the opposite or west bank of the river Irrawaddy, about fifty miles above Yenangyoung (see Sketch Maps, No. III.), as well as in the Yaw country, west of Pagan, and in the Chindwin Valley, north of Pagan; also at Minbu, about eighteen miles below Yenangyoung, on the west bank of the Irrawaddy. In Pegu, petroleum is found at Padaukpen, west of Thayetmyo, lower down the river; and at Yenatoung, west of Myanoung, still further south. In the Arakan islands, petroleum is obtained in the Barangas, Ramri and Cheduba (see Sketch Maps, No. II.). In Assam, drilling for petroleum has also been successfully prosecuted to the eastward of Dibrugahr (see Sketch Maps, No. V.). The oil has also been met with in the Punjab, near Rawal Pindi (see Sketch Maps, No. I.), as well as further north, near the Khyber Pass; and in Baluchistan several very productive wells have been drilled at Khátan, in the Mari hills.

In Java and Sumatra, the oil, which issues from natural fissures or artificial excavations, has long been an article of commerce among the natives, and in both islands productive wells have recently been drilled.* Petroleum has also been found in the north of the island of Labuan, and is reported to exist in north Central Borneo.

The petroleum wells in China are in the province of Sse-tchouen, and are thus described by L'Abbé Huc:

"When a salt well has been dug to a depth of 1000 feet, a bituminous oil is found in it that burns in water. Sometimes as many as four or five jars of 1000 pounds each are collected in a day. This oil is very fœtid, but it is made use of to light the sheds in which are the wells and the cauldrons of salt. The mandarins, by order of the prince, sometimes buy thousands of jars of it, in order to calcine rocks under water that render navigation perilous."

Natural gas is also largely used in China for heating purposes.

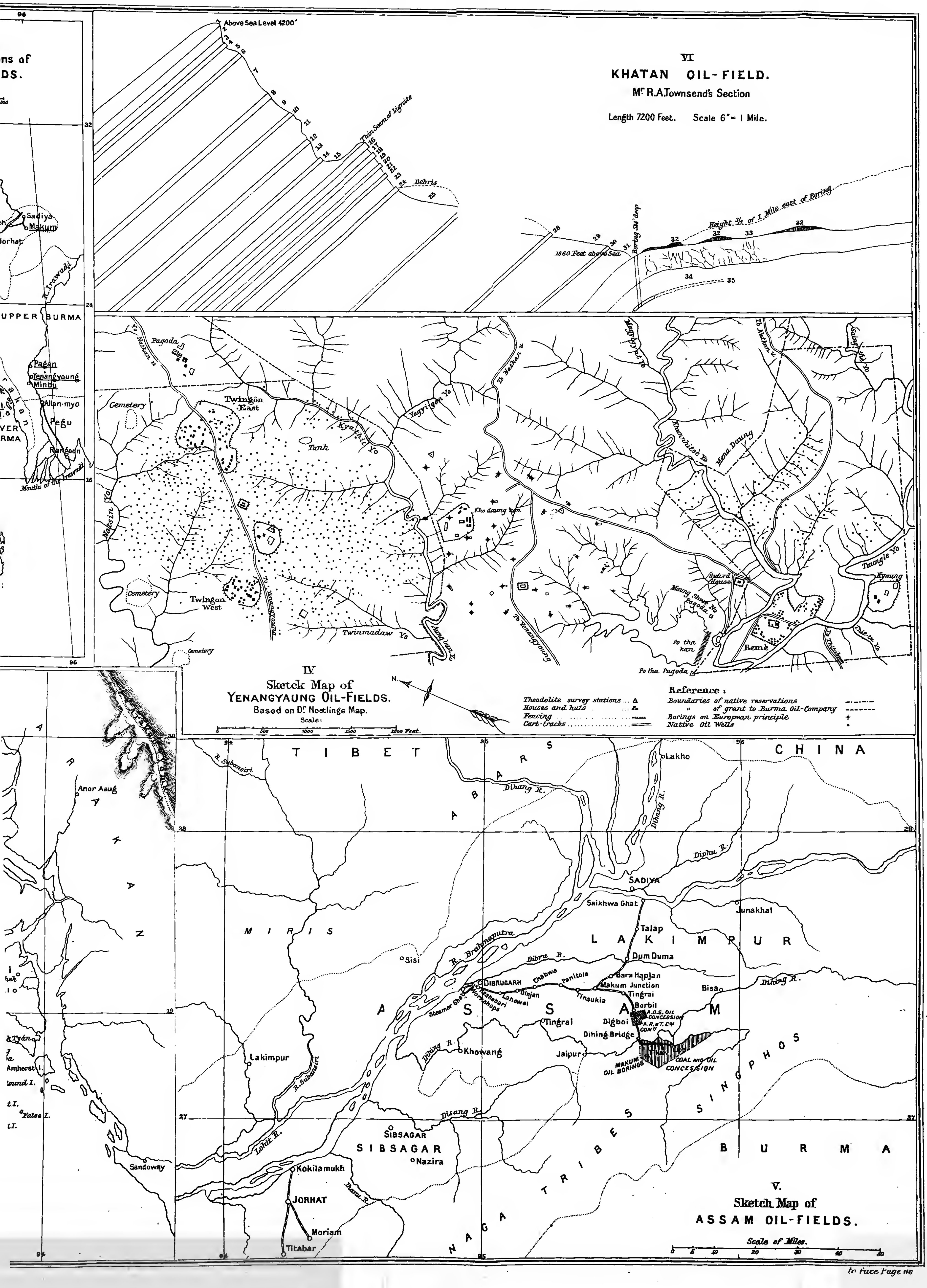
The petroleum deposits and petroleum industry of Japan have been described in detail by Mr. Lyman (Reports on the Geological Survey of Japan). In 1877, there were, according to Mr. Lyman, in the Echigo oil-fields, 522 producing wells, yielding in the aggregate about 9500 barrels of crude oil per annum; and in the province of Shinano, 22 producing wells yielding 1900 barrels.

There are several localities in Africa where surface indications of petroleum are met with. Attention was some time ago directed to the results of the explorations conducted by M. de Bay, at Gebel-el-Zeit, and at Jemseh, on the west coast of the Red Sea, at the entrance of the Gulf of Suez, and it was regarded as not improbable that in these localities as well as in the neighbouring island of Jafatin, oil might be found in quantity. The Egyptian Government engaged Dr. Tweddle to carry on the work of development, and wells were drilled, but without satisfactory results. In Algeria, petroleum is found at Aïn Zeft, in the province of Oran.

In the West Indies, petroleum has for a lengthened period been known to occur. The petroleum of Barbados was formerly imported under the name of Barbados tar, and the asphaltum from the pitch lake of Trinidad has for many years been an important article of commerce. This deposit is about three miles in circumference, and is described as a mass of asphaltum firm enough to bear a team of horses, but still somewhat plastic. The

* In Sumatra, especially, the industry appears likely to assume great importance.

FORSTER GROOM & Co 15, Charing Cross, S.W.



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asphaltum is broken out with picks, and only a foot or two of the surface is removed, the pitch below this becoming soft and plastic. The excavations made fill again in a short time with the fluid material from below, the new deposits hardening very soon into asphaltum. The visible supply is very large, the surface to a depth of one foot being estimated to contain 116,678 tons of asphaltum.

Petroleum and asphalt are likewise met with in Cuba.

In the Dominion of Canada, petroleum is obtained in considerable quantity in Ontario, as already mentioned. It is also found at Gaspé, where drilling operations are now in progress. Along the Athabasca, Vermilion, and Mackenzie rivers there are important indications pointing to the conclusion that extensive deposits of petroleum exist in this district. The oil has also been met with on Great Manitoulin Island; in British Columbia, at Crow's Nest Pass, in the Rocky Mountains; on the Tar Islands, Queen Charlotte's Islands; as well as in Newfoundland, Nova Scotia, and New Brunswick.

Petroleum is produced, as already stated, in the United States in Pennsylvania, New York, Ohio, West Virginia, Colorado, California, Indiana, Kentucky, and Tennessee, Illinois, Kansas and Texas. It also occurs in Alabama, Florida, Michigan, Missouri, Louisiana, Nebraska, Montana, Wyoming, Dakota, and New Mexico.

In Mexico there are several localities where promising indications of petroleum occur, and in Venezuela, on the shores of Lake Maracaibo, considerable deposits are believed to exist. In Columbia, Ecuador, and the Argentine Republic, petroleum has been met with; but the only localities in South America where systematic drilling has been carried on are in Peru. As long ago as 1876, a productive well was sunk near Zorritos, by Mr. Prentice, and a refinery was subsequently erected, but the outbreak of war caused the industry to be abandoned. At a later date the development of the Peruvian oil-fields was recommenced, and drilling operations are now being conducted by several companies.

In New Zealand, petroleum is found on the sea beach at Taranaki, New Plymouth, and a well has recently been drilled in this locality with a very promising result; it also occurs at Poverty Bay, on the east coast of North Island. and at Manutahi, Waipu.

CHAPTER II.

VII. Geology of Petroleum.

PETROLEUM occurs in all geological formations, from the Silurian up to the Tertiary; it is, however, found chiefly in the Silurian, Devonian, and Lower Carboniferous rocks (in the western hemisphere), and in the Eocene and Miocene formations (in the eastern hemisphere).

In Pennsylvania and New York, petroleum is found saturating strata of sand-rock. When first wells were drilled in America nothing was known about these strata; but ultimately, in the valley of Oil Creek, the existence of three well-defined "oil-sands" was ascertained. These oil-sands in the Oil Creek district are of considerable regularity as regards their thickness and the distance intervening between them, the first sand being forty feet thick, with an interval of 105 feet between it and the second sand, which is twenty-five feet thick; an interval of 110 feet occurring between the second sand and the third, and the thickness of the latter being thirty-five feet. In some localities, however, the second sand is split into two well-defined sands, with from fifteen to thirty feet of slates or shales intervening, and

this has given rise to the definition of a fourth sand. In drilling on high ground in the Oil Creek district, several upper sand-rocks were also perforated, and these were termed "mountain sands." In addition to the three regular sands, there was often found, about fifteen to twenty feet above the regular third sand, a fine-grained muddy grey sand from twelve to twenty-five feet thick; this was termed the "stray third."

The Venango oil-sand group is described by Mr. Carll * as a group, in the strictest sense of the term, having a well-defined top and bottom, and consisting of a mass of sandstone deposits from 300 to 380 feet thick, with layers of pebbles, and many local partings of slate and shale. These figures may, he states, be varied somewhat, but it will be found that a thickness of 350 feet will, in nearly every case, embrace all the sands belonging to the Venango group, even the fourth, fifth, and sixth sands, as the lower members of the group in some localities have been called. The oil is principally obtained in the third sand.

As the area of the oil-producing territory was extended, it was found that the underlying geological formation varied considerably, the sand-rock disappearing, and its place being taken by shales at the same geological horizon.

The several groups of oil-producing rocks are, as Mr. Carll remarks, locally well-defined under certain areas; but they have their geographical as well as their geological limits, and as far as is at present known, the geographical limit of one group never overlaps that of another. Hence it must not be presumed that each particular sandstone or its oil will be found in every locality where its horizon can be pierced with the drill, or that a measured section of the rocks in one place can be precisely duplicated in detail in another. Therefore, the most skilful oil-producer, the most expert geologist, cannot tell how many other oil horizons may exist at intermediate depths beneath the surface (that is, in the scale of the formation), but which have, as yet, escaped the oil-miner's drill.

Local names are given to the principal oil-bearing strata. Thus, in the Washington field there are the Gordon sand, the Gantz sand, the 50-feet sand, and the Manifold sand.

In Western Pennsylvania the dip of the oil-bearing strata is pretty regularly at the rate of from 20 to 30 feet to the mile from north-east to south-west.

The position of the wells with reference to the anticlinal and synclinal disposition of the strata is, by some producers, carefully studied.

In Western Pennsylvania, the sand-rock varies in character from a coarse-grained uncemented sandstone to a pebble conglomerate, composed of coarse pebbles of white, or slightly coloured, opaque quartz, overlaid by marls and slates, often highly silicated, forming very hard and impervious crusts. This pebble conglomerate consists of two varieties, occupying separate horizons, in one of which the pebbles are nearly spherical, and in the other flattened. Between these beds of sandstone or conglomerate that contain the oil are beds of shale, with which are thin beds of sand and "shells." These shells are described by Professor Lesley as hard crusts of white flint.

Professor Peckham † remarks that petroleum is found in the principal oil-producing territories in the United States and Canada, saturating porous strata, and overlying superficial gravels. It occurs in Canada and West Virginia beneath the crowns of anticlinals; whilst in Pennsylvania it occurs saturating the porous portion of formations that lie far beneath the influence of superficial erosion, like sand-bars in a flowing stream or detritus on a

* Pennsylvania Geological Survey Reports.
† United States Census Report, 1884.

beach. These formations or deposits, taken as whole members of the geological series, lie conformably with the enclosing rocks, and slope gently towards the south-west. The Bradford field, in particular, says Professor Peckham, resembles a sheet of coarse-grained sandstone, 100 square miles in extent, and from 20 to 80 feet deep, lying with its south-western edge deepest, and submerged in salt water, and its north-eastern edge highest, and filled with gas under an extremely high pressure.

Mr. Ashburner's classification of the petroleum deposits of the oil regions of Pennsylvania and New York has already been given (see p. 102), and his description of certain of the oil-sands in the districts enumerated may here be added. In the Allegany and Bradford districts, the oil-sand consists of a grey, black, dark-brown or chocolate-brown sand, of about the coarseness of the ordinary beach-sand of the New Jersey coast. In the Warren district, it presents somewhat the general appearance of the Bradford and Allegany sand, but is frequently coarser-grained, and sometimes contains small pebbles not known to have been found in the sands of the two other districts. The Venango oil-sands generally consist of a white, grey, or yellow pebble rock. The pebbles are water-worn, are sometimes as large as hazel-nuts, are loosely cemented together, and are generally bedded in fine sand.

The oil-bearing sandstones in the Washington field may be thus described:

Gordon sand—small black, grey, and white particles in equal proportions. Gantz sand—similar to Gordon sand, with the exception that the grains are larger. Fifty-feet sand—of a pale brown colour. Manifold sand —small red and grey particles in equal proportions. Stray sand—for the most part of a greyish colour, but with a few reddish particles intermixed.

The Trenton limestone is an important source of petroleum in Ohio; it is also oil-bearing in Indiana. In Kentucky and Tennessee, petroleum is found in the Ohio shales (Upper Devonian); whilst in Colorado it occurs, according to Professor Newberry, in the Middle Cretaceous beds, the Colorado shales. Professor Aughey states * that the Wyoming petroleum deposits originate in the Mesozoic formation, and probably in the Triassic section of it.

In California, petroleum, according to Professor Hanks,† undoubtedly occurs in the Tertiary formation. At Pico Cañon, he observes, the sand-rocks are stratified with much regularity, and are interstratified with plates or seams of gypsum (selenite); a black shale and a coarse conglomerate also occur here. Professor Peckham states that he observed the petroleum in Ventura county to be primarily held in strata of shale. Nowhere in this locality did he find the enormously thick sandstone, with which the shale was interstratified, saturated with the oil.

Dr. Hunt asserts ‡ that in Western Canada the oil-springs are upon the outcrop of the corniferous limestone, or of the overlying Hamilton shales, and are along the line of a broad and low anticlinal, which runs nearly east and west through the district. The corniferous limestone in Enniskillen, he adds, is overlaid by about 200 feet of marls and soft shales, abounding in the characteristic fossils of the Hamilton formation. To this succeed from 40 to 60 feet of quaternary clays and sands of fresh-water origin, through which the scanty natural oil-springs rise. On sinking wells, there is generally found reposing immediately upon the shales a layer of coarse gravel holding large quantities of petroleum, which is the oil of the so-called surface wells, and has accumulated beneath the clays. It is darker and thicker than that obtained directly from the rock below, on boring which fissures or

* Report on the Wyoming Oil Springs, by Samuel Aughey, Ph.D., Omaha, Nebraska, 1882.

† Fourth Annual Report of the Californian State Mineralogist, Sacramento, 1884.

‡ American Journal of Science. 1863.

seams are met with, from which petroleum issues in abundance, and often with great force. These oil-bearing veins are met with at depths varying from 40 to 100 feet in the rock. In the Athabasca region, petroleum is found in the Devonian rocks; it has also saturated the sandy beds of the cretaceous series.

Professor Hitchcock enumerated in the "Geological Magazine," in 1867, the following fourteen different formations from which petroleum has been obtained in North America (exclusive of the West Indies), and generally in commercial quantities; and Professor Peckham considers that developments since 1867 have added little, if anything, to the enumeration.

(*a*) Pliocene (since determined to be Miocene) of California.
(*b*) Cretaceous in Colorado and Utah, near lignite beds.
(*c*) Trias of North Carolina and Connecticut.
(*d*) Near the top of the Carboniferous rocks in West Virginia
(*e*) Shallow wells near Wheeling, West Virginia, and Athens, Ohio, not far from the Pittsburgh coal.
(*f*) 425 feet lower, near the Pomeroy coal-beds.
(*g*) At the base of the Coal-measures, in conglomerates or mill-stone grit.
(*h*) Small wells in the Archimedes limestone (Lower Carboniferous) of Kentucky.
(*i*) Chemung and Portage groups—certainly three different levels—in western Pennsylvania and northern Ohio.
(*j*) Black slate of Ohio, Kentucky, and Tennessee, or the representatives of the New York formation from the Genesee to the Marcellus slates. This is near the middle of the Devonian.
(*k*) Corniferous limestone and the overlying Hamilton group in Canada West, extending to Michigan.
(*l*) Lower Heldeberg limestone at Gaspé, Canada East. This is Upper Silurian.
(*m*) Niagara limestone near Chicago.
(*n*) In the equivalents of the Lorraine and Utica slate and Trenton limestone of the Lower Silurian, in Kentucky and Tennessee.

Vasilieff* states that the oil-bearing strata of the Apsheron Peninsula belong to the Lower Miocene series of the Tertiary epoch. The upper beds, consisting of fossiliferous limestone, have disappeared in the oil-region, the rocks of which are covered by deposits of alluvial origin. The oil-bearing beds extend in a north-east and south-west direction, and the dip, as well as it can be made out at present, ranges between twenty and forty degrees. The beds are composed of sand, calcareous clays, marls, and in places compact sandstone, often of great thickness, frequently penetrated by bands of pyrites. The calcareous clays are easily bored through. The oil-sands are in a semi-fluid condition when brought to the surface. A characteristic of these groups of oil-bearing rocks is the total absence of organic remains down to the maximum depth yet reached, while the upper beds of the series abound in shells of the Aral-Caspian order. The number of oil-bearing strata is unknown; three have up to the present been defined.

In the Illski district, two oil-sands are met with: one at a depth of about 200 feet, and the other, which is the more productive, at from 600 to 1200 feet below the surface.

In the Baku oil-fields, the dip is stated to range from 20° to 40°, the oil deposits, as in Pennsylvania, extending in a north-east and south-west direction. Vasilieff says that practice has justified the principle advocated

* Gorny Jurnal (Russian Mining Journal), 1885. Translated and abstracted by William Anderson, M.I.C.E., and published in the Minutes of the Proceedings of the Institution of Civil Engineers, London, 1885.

by Professor Romanoffsky that wells should not be drilled near the outcrop of the oil-bearing strata, nor at anticlinal bends, but should strike the beds at not less than 400 feet below the outcrop.

In the oil-fields of Galicia, the general succession of the strata, according to Mr. William Topley, F.R.S., is as follows, petroleum occurring in the divisions marked * :—

*Salt marl beds (Ozokerite)		Miocene
Magura and Kliwa sandstones	Oligocene of some authors	Eocene
*Menilite beds	*Upper	Eocene
Carpathian sandstone series	Middle	Cretaceous
	*Lower (Ropianka) beds	Neocomian

The "oil-belt" extends in a general north-west and south-east direction.

In Italy, petroleum is met with in the Tertiary formation. The strata are argillaceous, more or less marly, of a grey colour, with calcareous sand of a greenish colour, and sand containing mica in minute grains. Beneath the strata are hard masses of marl and sand.

In France and Spain, the oil occurs in Cretaceous and Tertiary beds. In a paper read at the 1891 meeting of the British Association, Mr. Topley stated that in north-west Germany petroleum was found in the Keuper beds, and more or less in other strata, up to and including the Gault; in the Rhone Valley and Savoy, in the Jurassic formation; in the Pyrenees and Spain, in the Neocomian and Cretaceous; in Elsass, in the Oligocene; in Bavaria, in the Lower Tertiary (Flysch); in Italy, in the Eocene; in Galicia and north-east Hungary, in the Neocomian to the Miocene; and in Poland, Roumania, and the Caucacus, in the Miocene.

In Mexico, and in the West Indies, the oil is found in the Tertiary formation. In Algeria, it occurs in the Lower Tertiary beds; in Egypt, in the Miocene formation, and in New Zealand in the Cretaceous and Tertiary strata.

In Burmah, petroleum occurs in the rocks of the Middle or Lower Tertiary epoch. In his report on the oil-fields of Twingaung and Beme, already referred to, Dr. Noetling expresses the belief that the petroliferous strata of the Yenangyoung district are of no later age than Miocene. They consist, he states, of laminated and clayey sands, sometimes a little indurated, so as to form soft sandstones. Some of the beds are highly calcareous, concretionary masses of sandy limestone abounding. Nodular concretions of a very hard quartzitic limestone are also found. The sandstone varies in colour from white or very pale yellow up to dark red and blue. The clays and sand-clays have a bluish-grey tint. Mr. R. A. Townsend † appears to be of opinion that the oil-bearing rocks of the Khátan field in Baluchistan, are Eocene.

In Assam, petroleum is found in the coal-bearing beds of the Middle Tertiary.

The occurrence of petroleum in coal-mines in England has already been referred to. As much as thirty-five tons was collected at the Southgate Colliery, near Chesterfield, in 1890. It is also found, in small quantities, in the Derbyshire lead-mines, which are worked in the carboniferous limestone. According to Mr. Topley, petroleum obtained from the sandstone beds in the coal-measures of Shropshire, was sold years ago under the name of Betton's British Oil. Mr. D. N. Steuart, chemist to the Broxburn Oil Company, in a paper (Jour. Soc. Chem. Industry, Feb. 20, 1887) descriptive of a petroleum spring met with in one of the company's shale-pits, states that the oil is found in a level, below the Broxburn and

* Report on the Petroleum Exploration at Khátan.

Dunnet seams of shale, which had been driven off the main shaft, through a series of stratified rocks consisting of calcareous bands and poor shale.

In the paper already referred to, Mr. Topley summarises the geological condition under which petroleum and natural gas occur as follows:

1. They occur in rocks of all geological ages, from Silurian upwards. The most productive areas are, Palæozoic in North America, Miocene in the Caucasus.

2. There is no relation to true volcanic action.

3. The most productive areas for oil in great quantity are where the strata are comparatively undisturbed. Oil, but in less abundance, frequently occurs when the strata are highly disturbed and contorted; but gas is rarely so found.

4. The main requisites for a productive oil- or gas-field are a porous reservoir (sandstone or limestone) and an impervious cover.

5. Both in comparatively undisturbed and in highly disturbed areas, an anticlinal structure often favours the accumulation of oil and gas in the domes of the arches.

6. Brine is an almost universal accompaniment of oil and gas.

In Ohio and Indiana, where the oil occurs in the Trenton limestone, the productive areas are mainly over anticlinals, gas occurring on the summit, and oil on the slopes. The Trenton limestone is highly fossiliferous, and the petroleum found in it is probably indigenous; but in the case of the sandstones, the source of the oil is probably the underlying fossiliferous shales. The Trenton limestone is only petroliferous where it has been dolomitised; but when thus transformed into a cavernous and porous rock it is capable, like the sandstone, of containing from one-tenth to one-eighth of its bulk of oil. The escape of the petroleum from these natural reservoirs is prevented by the impervious cover of shale.

Petroleum and natural gas are often found confined under great pressure,* the cause of which is clearly explained in the following extract from an article by Professor W. J. McGee, published in the "Forum" for July 1889, and reproduced by Mr. Topley in a paper on the Sources of Petroleum and Natural Gas, read at the Society of Arts, April 1891:

"The cause of this enormous pressure is readily seen in Indiana. The Cincinnati arch (in which the gas of the great Indiana field is accumulated) is substantially a dome, about fifty miles across, rising in the centre of a stratigraphic basin fully 500 miles in average diameter. Throughout this immense basin, the waters falling on the surface are in part absorbed into the rocks, and conveyed towards its centre, where a strong artesian flow of water would prevail were the difference in altitude greater; and the light hydrocarbons floating upon the surface of this ground water are driven into the dome, and there subjected to hydrostatic pressure equal to the weight of a column of water whose height is the difference in altitude between the water surface within the dome and the land surface of the catchment area about the rim of the enclosing basin. Accordingly, the static pressure is independent of the absolute altitude of the gas-rock and of its depth beneath the surface, except in so far as these are involved in the relative altitudes of the gas-rock and a catchment area, perhaps scores or even hundreds of miles distant. Gas pressure and oil pressure may, therefore, be estimated in any given case as readily and reliably as artesian water pressure; but whilst the water pressure is measured approximately by the difference in altitude between the catchment area and well-head, that of gas is measured approximately by the difference in altitude between catchment area and gas-rock, and that of oil is measured by the same difference, *minus* the weight

* In Indiana 300 to 350 lbs. per square inch; in the Findlay field, 450 to 500 lbs.; and in the Pennsylvania field from 500 to 900 lbs.

of a column of oil equal to the depth of the well. It follows that the static pressure of gas (as indicated at the surface) is always greater than that of oil, particularly in deep wells. It follows also that the pressure, whether of gas or oil, is not only constant throughout each field, but diminishes but slightly, if at all, on the tapping of the reservoir, until the supply is exhausted; and hence that pressure is no indication of either abundance or permanence of supply."

VIII. Origin of Petroleum.

Petroleum is usually considered to have been formed by the slow decomposition of vegetable or animal matter, either in the rocks in which it is found, or in underlying strata. Berthelot, however, in 1866* propounded the theory that petroleum resulted from the action of carbonic acid and steam on the alkali metals; and in the following year Mendeléeff, in an essay read before the Chemical Society of St. Petersburg, † gave in detail his reasons for believing petroleum to be the product of the action of water on metallic carbides, at a high temperature and under great pressure. Accepting La Place's hypothesis in regard to the formation of the earth, it is natural to conclude that metals, and especially iron, would be among the bodies first condensed, and would thus enter largely into the composition of the centre of the earth. As the crust became crumpled and cracked under the influence of the continued cooling and contraction of the core, crevices would be formed, through which water, now condensing on the surface, would find its way to the still highly heated compounds of carbon and iron or other metal. Decomposition of the water would ensue, with the production of hydrocarbons and metallic oxides. The former products would pass away to higher strata, where they would become condensed into the liquid form. This theory appears to have received such support as has been accorded to it mainly, though not wholly, on the ground of the supposed difficulty of accepting the principal alternative hypothesis in the absence of a carbon residue (such as would have resulted from the decomposition of vegetable and animal remains), and of evidence of the action of heat upon the oil-bearing rocks. Professor Peckham has, however, clearly pointed out ‡ that in the case of the petroleums of California and Texas, for instance, the strata from which they issue contain vast accumulations of animal remains; that petroleum is not asserted to be the product of high temperatures and violent volcanic action, but of slow and gentle changes at low temperature due to metamorphic action upon strata buried at immense depths; and lastly, that as regards the petroleum of New York, Pennsylvania, Ohio and West Virginia (to which Mendeléeff's theory probably had special reference) there is evidence that the oil is a distillate, and that the carbonised remains of organisms and evidences of heat action must be sought at a depth far below the unaltered rocks in which the petroleum is now stored. There is an additional argument which has been advanced in support of Mendeléeff's hypothesis—namely, that the supply of organic matter is inadequate. In respect to this, however, Professor Peckham points to the vast extent of the Devonian shales, and the immense quantity of fucoidal remains which this deposit contains, as an ample source, and he adds that if the Devonian black shales are inadequate, we may descend still lower in the geological series to the Nashville limestone and other Silurian rocks.

It seems unquestionable that the derivation of the very varied descrip-

* "Ann. Chim. Phys.," Dec. 1866.

† L'Origine du Petrole: "Revue Scientifique," Nov. 3, 1877.

‡ Census Report, 1884.

tions of petroleum met with has not been uniform, and this is a strong argument in favour of the theory that petroleum has been formed from animal and vegetable remains. Professor Peckham remarks that if petroleum be the product of what he terms "a purely chemical process," we should not expect to find palæozoic petroleums of a character corresponding with the simple animal and vegetable organisms that flourished at that period, and Tertiary petroleums containing nitrogen, unstable and corresponding with the decomposition products of more highly organised beings, but we should expect to find a general uniformity in the character of the substance, wherever found, all over the earth.

It has been already stated that the Tertiary petroleums are probably indigenous to the rocks in which they are found, and that the older petroleums have evidently been removed to the rocks wherein they are found by a process of distillation. Professor Peckham arranges the various kinds of bitumen from the solid to the gaseous, in the four following classes:

1. Those that form asphaltum and do not contain paraffin.
2. Those that do not form asphaltum and contain paraffin.
3. Those that form asphaltum and contain paraffin.
4. Solid bitumens that were originally solid when cold or at ordinary temperatures.

To the first class belong the petroleums of California and Texas, which are doubtless indigenous in the shales from which they issue. The animal remains in the oil-bearing strata, the presence of a considerable amount of nitrogen in the oils, and the fact that the fresh oils soon become filled with the larvæ of insects to such an extent that pools of petroleum soon become pools of maggots, point to the conclusion that these petroleums are of animal origin.

The second class includes the petroleums of New York, Pennsylvania, Ohio, and West Virginia. There seems to be ample ground for regarding these oils as of vegetable origin, and as products of distillation.

The third class of petroleum appears, in the opinion of Professor Peckham, to have been produced by the mingling of the two preceding classes of oils through the invasion of rocks containing indigenous petroleum by steam under high pressure.

The solid bitumens of the fourth class are regarded by Professor Peckham as in all cases manifestly the result of the action of heat on the organic matter in stratified rocks.

As regards the nature of the metamorphic action by which petroleum has been formed, Professor Peckham remarks of North-Eastern America, that it is sufficient for our purpose to know that from the Upper Silurian to the close of the Carboniferous periods, the currents of the primeval ocean were transporting sediments from north-east to south-west, sorting them into gravel, sand and clay, forming gravel bars and great sand beds beneath the riffles and clay banks, in still water, burying vast accumulations of seaweed and sea animals far beneath the surface. The alteration, due to the combined action of heat, steam, and pressure that resulted in the formation of the Appalachian system, from Point Gaspé, in Canada, to Look-out Mountain in Tennessee, involving the Carboniferous and earlier strata, distorting and folding them, and converting the coal into anthracite, and the clays into crystalline schists along their eastern border, could not have ceased to act westward along an arbitrary line, but must have gradually died farther and farther from the surface. The great beds of slate and limestone, containing fucoids, animal remains, and even indigenous petroleum, must have been invaded by this heat action to a greater or less degree, and thus, in accordance with the theory of Professor Lesley, a chronic evaporation or distillation of the whole mass of oil in the crust of the earth (within reasonable

reach of the surface) has been going on, converting the animal and plant remains into oils, the light oils into heavy oils, the heavy oils into asphalte and albertite; the process being accompanied by the liberation of gas.

IX. Physical Characters of Petroleum.

Petroleum, in the widest sense of the term, occurs in all forms from the gaseous to the solid. In its liquid form it varies greatly in physical properties, some descriptions being nearly colourless and very mobile, while others are black and viscid. Samples from any one producing territory, and even from the same level of oil-bearing rock in that territory, are sometimes quite dissimilar in character. Thus, Dr. Krämer instances the case of two wells in the Oelheim district, near Hanover, of the same depth, and within two metres of each other, one of which yields an oil of sp. gr. 0.880, and the other an oil of sp. gr. 0.905. The extreme limits of variation in the specific gravity of samples of crude petroleum examined by the writer are 0.771 and 1.000.

The writer has had occasion during the past twenty-five years to examine a large number of samples of crude petroleum from different parts of the world, and some of the results thus obtained are given in the subjoined tables.

America.

Locality.	Specific Gravity.	Locality.	Specific Gravity.
California—		Pico Cañon district, 15 . .	0.854
Pico Cañon district, 1 .	0.827	„ „ 16 . .	0.837
„ „ 2 .	0.835	„ „ 17 .	0.846
„ „ 3 .	0.831	„ „ 18 . .	0.853
„ „ 4 .	0.838	„ „ 19 . .	0.842
„ „ 5 .	0.837	„ „ 20 . .	0.837
„ „ 6 .	0.828	„ „ 21 . .	0.841
„ „ 7 .	0.844	„ „ 22 . .	0.850
„ „ 8 .	0.839	„ „ 23 . .	0.842
„ „ 9 .	0.836	„ „ 24 . .	0.844
„ „ 10 .	0.847	„ „ 25 . .	0.840
„ „ 11 .	0.827	„ „ 26 . .	0.846
„ „ 12 .	0.832	„ „ 27 . .	0.843
„ „ 13 .	0.828	„ „ 28 . .	0.865
„ „ 14 .	0.859	„ „ 29 . .	0.927

The colour of the whole of these samples was brown.

Locality.	Specific Gravity.	Flashing Point (Abel Test).	Colour.
		F.	
Kansas	0.927	224°	Black
Canada (Petrolia)* . .	0.858	—	Dark brown
„ (Gaspé), 1 . . .	0.881	180°	Brown
„ „ 2 . . .	0.856	65°	„
„ „ 3 . . .	0.853	54°	Dark brown
„ „ 4 . . .	0.877	90°	„
„ „ 5 . . .	0.939	280°	Black
„ „ 6 . . .	0.921	210°	Brown
„ „ 7 . . .	0.948	—	„
„ „ 8 . . .	0.871	104°	„
„ „ 9 . . .	0.894	—	„
„ „ 10 . . .	0.847	46°	„
„ „ 11 . . .	0.844	60°	„

* The sp. gr. of the crude petroleum from the Petrolia field usually ranges from 0.859 to 0.877, while the product from the Oil Springs field has a sp. gr. ranging from 0.844 to 0.854.

Locality.	Specific Gravity.	Flashing Point (Abel Test).	Colour.
		F.	
Peru, 1	0.859	38°	—
„ 2	0.940	248°	—
„ 3	0.920	122°	—
Ecuador, 1	0.953	—	Deep brownish-red
„ 2	0.928	—	„
Mexico, 1	0.874	111°	—
„ 2	0.882	126°	Brownish-red
„ 3	0.942	294°	Black
„ 4 *	0.946	262°	—
Argentine Republic	0.935	—	Black

Locality.	Specific Gravity.	Colour.
Bradford, 1	0.810	Reddish-brown
„ 2	0.819	„
Parker (Clarion)	0.797	„
„ (Kansas City)	0.789	„
Thorn Creek	0.802	„
Stoneham	0.802	Dark amber
Macksburg	0.829	Reddish-brown
Lima	0.839	Brownish-black
Washington, 1	0.790	Yellow
„ 2	0.777	„
„ 3	0.798	Amber
„ 4	0.798	Yellow
„ 5	0.800	Amber
„ 6	0.804	„
„ 7	0.792	Yellow
„ 8	0.819	Amber
„ 9	0.775	Yellow
„ 10	0.820	Amber
„ 11	0.801	„
„ 12	0.816	Brown
„ 13	0.814	„
„ 14	0.828	„
„ 15	0.792	Dark brown
„ 16	0.788	Yellow
„ 17	0.771	„
„ 18	0.801	Amber
„ 19	0.799	„
„ 20	0.780	Dark brown
„ 21	0.777	Yellow
„ 22	0.771	„
„ 23	0.786	„
„ 24	0.772	„
„ 25	0.772	„
„ 26	0.797	Amber
„ 27	9.792	„
„ 28	0.814	„
„ 29	0.808	„
„ 30	0.820	Dark brown
Wyoming, 1	0.912	Very dark brown
„ 2	0.912	„
„ 3	0.912	„
„ 4	0.910	„
„ 5	0.944	Brownish-black
„ 6	0.911	Very dark brown
„ 7	0.945	Brownish-black
California (Pico Cañon)	0.844	Dark brown
„ (Puente)	0.880	Black

* Viscosity at 70°, 73.11 (Raps oil at 60° F.=100), cold test, 0° F.

Russia.

Locality.	Specific Gravity.	Flashing Point. (Abel Test).	Colour.
		F.	
Balakbani, 1	0.879	—	Dark brown
" 2	0.873	93°	"
Surakbani	0.780	—	Pale yellow
Tiflis	0.976	320°	Almost black
Illski, 1	0.853	—	Dark brown
" 2	0.942	—	Brownish-black
Koudako, 1	0.860	—	Very dark brown
" 2	0.936	—	Brownish-black
Kertch (Crimea) . . .	0.887	—	—

The sp. gr. of the petroleum yielded by the flowing wells in the Baku district during the year 1889 ranged from 0.854 to 0.899, the oils of lowest density not being in all cases obtained from the deepest wells.

Burmah, Assam, and Baluchistan.

Locality.	Specific Gravity.	Setting Point.	Flashing Point (Abel Test).	Viscosity by Redwood's Viscometer (Rape oil at 60° F.=100) at 90° F.
		F.	F.	
Upper Burmah (Yenangyoung) Twinza's wells, 1	0.887	82°	110°	10.21
" " " " 2	0.937	Remains fluid at 0°	150°	25.86
" " " Drilled well .	0.869	80°	62°	—
" " " " .	0.870	78°	80°	—
" " " " .	0.875	82°	83°	10.07
" (Pagan district), 1 . . .	0.837	60°	—	5.91
" " " 2 . . .	0.832	70°	70°	5.54
" (Minbu)	0.999	35°	294°	703.06
Pegu (west of Thayetmyo) 1	0.854	72°	80°	6.38
" " " 2	0.859	76°	110°	7.81
" " " 3	0.870	80°	126°	8.78
Arakan I. (Ramri) mud volcano, 1	0.818	—	—	—
" " native pits 2	0.866	—	—	—
" " " 3	0.890	Below 10°	125°	10.21
" " " 4	0.834	do.	45°	—
" " " 5	0.825	20°	62°	—
Baranga I. (Eastern)	0.835	—	—	—
" (Western)	0.888	—	—	—
Assam, 1	0.933	—	—	—
" 2	0.940	—	212°	14.2
" 3. from drilled well, Digboy . .	0.858	—	43°	—
Baluchistan (Khatan)* from drilled well . .	1.000	—	280°	—

Galicia.

	Specific Gravity.	
	Lowest.	Highest.
Eastern end of belt, Sloboda-Rungurska .	0.830	0.868
Intermediate portion of belt, Ustrzyki district	0.835	0.844
Western end of belt, Wietzno district .	0.846	0.859

* A viscid oil of black colour.

Fifteen Wells in the District of Sloboda-Rungurska.

No.	Depth in Metres.	Specific Gravity.	No.	Depth in Metres.	Specific Gravity.
1	213	0.842	9	202	0.863
2	194	0.868	10	280	0.837
3	189	0.835	11	305	0.839
4	164	0.850	12	280	0.837
5	225	0.838	13	282	0.864
6	275	0.845	14	250	0.830
7	282	0.844	15	311	0.839
8	274	0.833			

Five Wells in the Ustrzyki District.

No.	Depth in Metres.	Specific Gravity.	No.	Depth in Metres.	Specific Gravity.
1	183	0.835	4	232	0.836
2	173	0.844	5	229	0.841
3	183	0.841			

Miscellaneous.

Locality.	Specific Gravity.	Flashing Point (Abel Test). F.	Colour.
Roumania, 1	0.859	123°	Dark brown
" 2	0.845	Below 20°	"
" 3	0.860	75°	"
" 4	0.861	72°	"
" 5	0.839	87°	"
" 6	0.890	80°	"
" 7	0.896	85°	"
" 8	0.882	57°	"
" 9	0.846	—	"
" 10	0.899	—	"
Hungary	0.907	188°	Reddish-brown
Germany (Oelheim)	0.913	—	Brownish-black
" (Wietze-Steinförde), 1	0.951	200°	—
" " " 2	0.943	150°	—
" " " 3	0.941	—	—
" (Horst), 1	0.910	98°	Very dark brown
" " 2	0.872	84°	"
England (Derbyshire)	0.857	—	Black
Spain	0.921	—	Brownish-black
Italy (Montechino)	0.787	13°	Straw
" (Miano), 1	0.867	36°	Brownish-red
" " 2	0.832	21°	"
Zante, 1	1.020	—	Black
" 2	1.005	—	"
Algeria, 1	0.921	60°	Dark brown
" 2	0.924	—	"
" 3	0.981	218°	"
Red Sea *	0.945	144°	Black
Java	0.881	—	—
Trinidad, 1	0.980	330°	"
" 2	0.961	190°	"
" 3	0.952	—	"
Barbados	0.945	240°	Dark brown
"	0.957	—	—
New Zealand (Taranaki), 1	0.971	236°	Brownish-black
" " 2	0.843	70°	Reddish-brown
" " 3	0.828	—	Brown
Persia, 1	0.777	—	Straw
" 2	1.016	—	—

* M. A. Pappel, Chief Chemist in the Khedivial Laboratory, Cairo, has furnished the writer with particulars of two samples of crude petroleum from the Red Sea coast examined by him. The specific gravities of these samples were 0.908 and 0.933.

The odour of the great majority of these samples was not unpleasant, but the Lima (Ohio) and Petrolia (Canada) oils, as well as the heavy oil (sample No. 2) from Persia, had an offensive smell, due to the presence of sulphur compounds, and the Wyoming oils had also a somewhat disagreeable odour.

The co-efficient of expansion of petroleum varies with its specific gravity, as is shown by the following table:

Specific Gravity at 15° C.		Expansion co-efficient for 1° C.
Under 0.700	...	0.00090
0.700 to 0.750	...	0.00085
0.750 to 0.800	...	0.00080
0.800 to 0.815	...	0.00070
Over 0.815	...	0.00065

The rate of expansion has also been found to vary according to the temperature.

In commercial practice, it is customary to add to or subtract from the recorded sp. gr. 0.0004 for every 1° F. above or below 60° F., and this is found to afford a sufficiently close approximation to the truth for business purposes in the case of most of the various descriptions of kerosene.

Tables for calculating the alterations in volume of crude petroleum with accuracy are in use in America. These tables were constructed on Gay-Lussac's formula,

$$\frac{1 + k\,t}{1 + a\,t} = \frac{P - p}{P}$$

Where P = weight of the liquid before heating;

p = weight of the fluid after heating, and after the apparent expansion has been removed;

t = change of temperature;

k = co-efficient of expansion of the glass;

a = co-efficient of expansion of the fluid.

The solid form of petroleum is represented by ozokerite, by asphaltum, by elaterite (the so-called mineral india-rubber of Derbyshire), and, perhaps, by the "coorongite" of South Australia. By some, however, coorongite is believed to be a vegetable hydrocarbon of recent formation.

Ozokerite varies from a very soft material to a black substance as hard as gypsum. The density of ozokerite ranges from .850 to .950, and its melting point from 58° to 100° C. (136°–212° F.) It is soluble in benzene, oil of turpentine, and petroleum. It is a good insulator, and has been recommended for use as such, in admixture with 50 per cent. of india-rubber. Ordinary commercial Galician ozokerite has the following properties: it is soft and plastic, and has a very fibrous fracture. The colour varies from light yellow to dark brown, and it frequently has a greenish hue, owing to dichroism. It becomes negatively electrical by friction, and exhales an aromatic odour. It becomes more plastic on heating, and usually melts at about 62° C. (144°F.).

The crude ozokerite found in the island of Tchéleken, on the Trans-caspian coast, is described as a brownish-black sticky substance.

Asphaltum is a black or very dark brown substance, usually hard and brittle, and in that condition exhibiting a resinous fracture.

X. Chemistry of Petroleum.

Crude petroleum in the liquid form consists principally of carbon and hydrogen, usually in the proportion of about 85 per cent. of the former to 15 per cent. of the latter; but there are sometimes present in small quantities oxygen, nitrogen, and sulphur.

Reichenbach examined paraffin in 1830, and rock oil four years later Early attempts to determine the composition of petroleum were also made by Laurent. In 1857, De la Rue and Müller described the products they had obtained from Rangoon petroleum. In 1863, Schorlemmer isolated some of the constituents of Pennsylvanian petroleum, and about the same time Pelouze and Cahours succeeded in separating from this oil twelve distinct hydrocarbons, which were found to be homologues of marsh gas (CH_4), and of which the general formula was C_nH_{2n+2}. Of the more volatile hydrocarbons, namely, those boiling between 0° and 130° C. (32° and 266° F.), there have been shown to be, in Pennsylvanian petroleum, at least two series present; those of the first series, which have the higher boiling points, being normal, whilst those of the second agree, for the most part, in boiling point, with the corresponding synthetically prepared iso-paraffins. There are grounds for believing that a third series occurs in the fraction referred to.

From crude Pennsylvanian petroleum, as it issues from the earth, methane, ethane, and propane are given off, so that from this description of petroleum the following hydrocarbons have been separated.

Methane	CH_4
Ethane	C_2H_6
Propane	C_3H_8

Name.	Formula.	Specific Gravity. Normal.	Boiling Point. Normal.	Boiling Point. Iso.
Butane . .	C_4H_{10}	0.645 at 0° C.	0° C.	—
Pentane . .	C_5H_{12}	0.645 at 0° C.	38° C.	30° C.
Hexane . .	C_6H_{14}	0.63 at 17° C.	69° C.	61° C.
Heptane . .	C_7H_{16}	0.712 at 16° C.	98° C.	91° C.
Octane . .	C_8H_{18}	0.726	124° C.	118° C.
			Boiling Point.	
Nonane .	C_9H_{20}	0.71 at 15° C.	136° to 138° C.	
Decane .	$C_{10}H_{22}$	0.757 at 15° C.	160° to 162° C.	
Endecane .	$C_{11}H_{24}$	0.765 at 16° C.	180° to 184° C.	
Dodecane .	$C_{12}H_{26}$	0.776 at 20° C.	196° to 200° C.	
Tridecane .	$C_{13}H_{28}$	0.792 at 20° C.	216° to 218° C.	
Tetradecane	$C_{14}H_{30}$	—	236° to 240° C.	
Pentadecane	$C_{15}H_{32}$	—	255° to 260° C.	

Methane is a colourless, inodorous gas, burning with a yellow flame of little luminosity. Ethane is also a colourless, odourless gas. Propane liquefies at – 20° C. (–4° F.). Normal butane condenses at 0° C. (32° F.) to a liquid.

The less volatile portions of American crude petroleum, boiling above 260° C. (500° F.), contain paraffins of still higher order, those containing 20 carbon atoms, or more, being crystalline solids. Warren isolated from American petroleum the hydrocarbons, $C_{10}H_{20}$ to $C_{12}H_{24}$, but these compounds, however, according to Markovnikoff, who terms them naphthenes, differ from the olefines. Schorlemmer found traces of hydrocarbons of the benzene series in American petroleum. From the least volatile portion of American crude petroleum, a peculiar solid crystalline hydrocarbon was separated by Morton in 1873. To this hydrocarbon, which in its reactions resembled anthracene, the name of thallene was given. Morton subsequently found that the spectrum of thallene differed from that of anthracene. The least volatile products of distillation were afterwards examined by Prunier; and more recently by Divers and Nakamura, who have isolated a compound of the formula $(C_4H_3)_n$, boiling between 280° and 285° C. (536° and 545° F. Besides thallene, anthracene, chrysene, pyrene, and fluorene are also present in small quantity in crude petroleum.

Caucasian petroleum has been examined by Beilstein and Kurbatow ("Ber." xiii. 1813; "Journ. Chem. Soc.," xl. 159); by Schützenberger and Jonine ("Compt. Rend.," xci. 823; "Journ. Chem. Soc.," xl. 705); by Markovnikoff and Oglobin ("Journ. Chem. Soc.," xlii. 390; xlvi. 1276), and by Le Bel ("Compt. Rend.," ciii. 1017). The researches of these chemists have shown that the material is altogether different in composition from Pennsylvanian petroleum, and that it consists chiefly of hydrocarbons of the C_nH_{2n} series, isomeric both with the olefines, or true homologues of ethylene, and with the hexahydrides of the benzene hydrocarbons, $C_nH_{2n-6}H_6$, obtained synthetically by Wreden. These hydrocarbons, which are the so-called naphthenes already referred to, exhibit the closest resemblance to the paraffins, but are of higher density than their isologues, and boil at somewhat lower temperatures than the isomeric olefines and the normal paraffins containing the same number of carbon atoms, and at approximately the same temperatures as the synthetically prepared benzene compounds, as the following examples indicate.

	Specific Gravity at 0° C.	Boiling Point.
C_8H_{18} (normal octane) . .	0.7188	124° C.
C_8H_{18} (octonaphthene) . .	0.7714	119° C.
$C_{12}H_{26}$	0.7655	202° C.
	Specific Gravity at 17° C.	
$C_{12}H_{24}$	0.8027	196° C.

The naphthenes are attacked by chlorine, forming chlorinated derivatives; but on oxidation are completely destroyed, without furnishing characteristic products. The following table contains a list of the hydrocarbons of this group, which have been isolated from Caucasian petroleum.

	Boiling Point.		Boiling Point.
C_8H_{16}	119° C.	$C_{12}H_{24}$	196° C.
C_9H_{18}	136° C.	$C_{14}H_{28}$	240° C.
$C_{10}H_{20}$	161° C.	$C_{15}H_{30}$	247° C.
$C_{11}H_{22}$	180° C.		

Caucasian petroleum also contains benzenes (pseudocumene, several isomerides of cymene, and also of its next homologue) and other benzenoid hydrocarbons. Neutral and acid oxygenated compounds are also present, Markovnikoff having found in a fraction boiling between 220° and 230° C. (428° and 446° F.) as much as 5.25 per cent. of oxygen. Solid hydrocarbons are found, as a rule, only in very small quantities in Caucasian petroleum.

Galician petroleum has been shown by Lachowicz ("Annalen der Chimie," ccxx. 188; "Journ. Soc. Chem. Ind.," ii. 473) and by Pawlewski ("Ber.," xviii. 1915) to contain a notable proportion of hydrocarbons of the aromatic (C_nH_{2n-6}) series, the latter chemist having found as much as 2 per cent. of these compounds (chiefly benzene and paraxylene). Aromatic hydrocarbons have also been found by C. Engler ("Journ. Soc. Chem. Ind.," i. 314) in Hanoverian petroleum.

From "Rangoon tar," presumably crude petroleum from the Yenangyoung district, Upper Burmah, Warren and Storer obtained the paraffins C_7H_{16} to C_9H_{20}, the olefines from C_9H_{18} to $C_{13}H_{26}$, besides xylene, cumene and naphthalene.

In some descriptions of Californian petroleum, as much as 1.1 per cent. of nitrogen occurs, and the so-called Mecca oil found in Ohio is stated to contain 0.23 per cent. of this element.

Sulphur is a not uncommon constituent of certain petroleums, notably

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	Petrolia, Canada.	West Bloomfield, New York.	Olean, New York.	Fredonia, New York.	Pioneer Run, Venango Co., Pa.	Barn's Well, near St. Ive, Butler Co., Pa.	Harvey Well, Butler Co., Pa.	Cherry Tree, Indian Co., Pa.	Leechburg.	Creighton.	Penn. Fuel Co.'s Well, Murraysville.	Fuel Gas Co.'s Well, Murraysville.	Roger's Gulch, Wirt Co., W. Virginia.	Gas from Marsh Ground.	Baku on the Caspian.	Occluded in Wigan Cannel.	Blower in Coal Pit, S. Wales.
Constituents :—																	
Hydrogen	Chiefly marsh gas, with some ethane and carbonic acid.	—	—	Marsh gas, ethane and butane.	Chiefly propane, with small quantities of carbonic acid and nitrogen.	6.10	13.50	22.50	4.79	—	Marsh gas with a little carbonic acid.	19.56	Marsh gas, with small quantities of nitrogen, and 15.86 per cent. carbonic acid.	—	0.98	—	—
Marsh gas		82.41	96.50			75.44	80.11	60.27	89.65	96.34		78.24		47.37	93.09	80.69	95.42
Ethane		—	—			18.12	5.72	6.80	4.39	—		—		—	—	4.75	—
Propane		—	—			trace	—	—	trace	—		—		—	—	—	—
Carbonic acid		10.11	—			0.34	0.66	2.28	0.35	3.64		—		3.10	2.18	6.44	0.60
Carbonic oxide		—	0.50			trace	trace	trace	0.26	—		—		—	—	—	—
Nitrogen		4.31	—			—	—	—	—	—		—		49.39	0.49	8.12	3.98
Oxygen		0.23	2.00			—	—	—	—	—		2.20		0.17	—	—	—
"Illuminating hydrocarbons"		2.94	1.00			—	—	—	0.56	trace		—		—	3.26	—	—

1. Fouqué, "Compt. Rend.," lxvii 1045.
2. H. Wurtz, "Am. J. Arts Sci.," [2] xlix. 336.
3. Robert Young.
4. Fouqué, "Compt. Rend.," lxvii. 1045.
5. " " "
6. S. P. Sadtler, Report L. 2nd Geol. Surv. Pa.
7. " " 3rd "
8. " " "
9. " " "
10. F. C. Phillips.
11. Robert Young.
12. Rogers.
13. Fouqué, "Compt. Rend.," lxvii. 1045.
14. Bischof's, "Chem. Geol.," i. 730.
15. " " "
16. J. W. Thomas, "Journ. Chem. Soc.," 1876, ii. 144.
17. " " " "

of those which occur in Canada and in Ohio. An oil found in the Kirghish Steppe is stated to contain 1.87 per cent. of sulphur, and Delachanal * found 3.02 per cent. of sulphur in the asphaltum of the Dead Sea.

In 1875, Hell and Meidinger obtained, from Wallachian petroleum, an acid, forming alkali salts resembling soft soap. The analysis of the acid, the ether, and the silver salt, agreed best with the formula $C_{11}H_{20}O_2$. These chemists expressed the opinion that heavy Wallachian petroleum contains acids in all probability belonging to the homologous series.

The table, on p. 132, giving the composition of natural gas, was published in the Report of the Committee on Natural Gas of the Engineers' Society of Western Pennsylvania.

The following results of analyses of natural gas were obtained by Mr. Carnegie at his works near Pittsburg.

	1	2	3	4	5	6
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Marsh gas	72.18	65.25	60.70	49.58	57.85	75 16
Hydrogen	20.12	26.16	29.03	35.92	9.64	14.45
Ethylic hydride	3.6	5.5	7.92	12.30	5.20	4.8
Olefiant gas	0.7	0.8	0.98	0.6	0.8	0.6
Oxygen	1.1	0.8	0.78	0.8	2.1	1.2
Nitrogen	nil	nil	nil	nil	23.41	2.89
Carbonic acid	0.8	0.6	nil	0.4	nil	0.3
Carbonic oxide	1.0	0.8	0.58	0.4	1.0	0.6

Ozokerite contains 85.7 per cent. of carbon, and 14.3 per cent. of hydrogen, and consists of a mixture of hydrocarbons in various proportions.

CHAPTER III.

XI. Primitive Methods of obtaining Crude Petroleum.

The method adopted by the Seneca Indians in the collection of crude petroleum near Cuba, N.Y., which consisted in skimming it off the surface of water with boards, has already been described. Woollen cloths were also used to absorb the oil, and occasionally the pool of oil-covered water was surrounded by a stone coping to increase its depth.

Professor Peckham records the statement that near Burning Springs, West Virginia, petroleum was collected early in this century "by digging trenches along the margin of the creek, down to a bed of gravel a few feet below the surface. By opening and loosening, with a spade or sharpened stick, the gravel and sand, which is only about a foot thick, the oil rises to the surface of the water with which the trench is partially filled. It is then skimmed off with a tin cup and put up in barrels for sale. In this way from 50 to 100 barrels are collected in a season."

From the remotest periods, pits and wells have been dug in various countries for the purpose of obtaining petroleum. The account given by Herodotus of the collection of petroleum from such a well near Susa has already been noticed.

The method adopted in the digging of wells in the oil-fields of Japan has been described in detail by Mr. Lyman.† It is stated that the work is carried ou by two men, one of whom digs in the morning, from nine o'clock

* "Compt. Rend.," xcvii. p. 191.
† Reports of the Geological Survey of Japan.

until noon, and the other from noon until three. The one who is not digging, works a blowing machine which delivers fresh air at the bottom of the shaft. The blowing apparatus is a wooden box about six feet long, three feet wide, and two feet deep, with a cover of slightly less length and width turning upon a horizontal axis over a vertical partition, which divides the box transversely into two compartments. The workman continually walks from one end of the cover to the other, his weight causing the ends to be depressed alternately. At his first step on each end he stamps his foot, and thus closes with a jerk a valve (0.3 foot square) which again opens by its own weight when the cover rises. The air is in this manner driven first from one end of the apparatus and then from the other into an air-pipe about 0.8 foot square, provided at the top with a valve for each end of the blower. The air-pipe is constructed of wood, and is fixed in one corner of the well, which is square. In the other corners are strong timbers which are held in their places by lighter cross-pieces so arranged as to form a ladder for descending and ascending. The earth or rock excavated is brought to the surface in rope nets attached to a rope passing over a wheel one foot in diameter, fixed under a roof covering the mouth of the well. The nets are drawn up by three men, two of whom stand at the corner of the well on one side, while the third takes up his position in a trench two or three feet deep, and eighteen inches wide, dug parallel to the side of the well. The digger has a rope fastened round his body under the arms for the purpose of raising him from the well in the event of his being overpowered by the petroleum vapour. The wells are about three and a half feet in diameter, and are excavated in the manner described to the remarkable depth of from 600 to 900 feet. At this depth there is so little light that the work has usually to be suspended at three o'clock in the day. The oil is skimmed from the surface of the water which collects in the well, and is drawn up in buckets. Mr. Lyman is of opinion that it would not be practicable to introduce in Japan the system of drilling with steam power adopted in America and elsewhere, on account of the cost of the necessary machinery, the difficulty of transporting the machinery in a country almost wholly without waggon roads, the heavy expense of fuel in the locality, and the small yield of the wells.

The cost of a well 900 feet in depth in the Echigo field in Japan, is stated to be only about £200, which Mr. Lyman considers to be little more than a third of the expense of drilling to the same depth in England or America.* Moreover, a dug well can be entered for cleaning or repairing, and such a well admits of the comparatively large surface for oil to percolate through being considerably extended by driving horizontal galleries from the vertical shaft. There are, however, as Mr. Lyman points out, some improvements which might advantageously be introduced into the present system. Thus, at present the well is lighted by means of a sheet of yellowish translucent oil paper fixed over the mouth at an angle of 45 degrees with the horizon across an opening in the roof of the grass hut covering the well, and Mr Lyman suggests that mirrors should be used to reflect light down the shaft and into the horizontal galleries. These galleries are at present so dark that they cannot be excavated to a greater length than about a dozen feet. A flame cannot be used in the well on account of the presence of inflammable gas, but the incandescent electric light, if not too costly, might be employed, and the working hours thus extended. A better system of ventilation might also be adopted; and the use of pumps for raising the water and oil, as well as of a water-tight casing, which might be made of timber, to prevent the influx of water, would also facilitate the collection of the petroleum. As an illustration of the cheapness of the

* It may be added that a drilled and cased well of about this depth frequently costs in the Baku oil-field as much as £2000.

present system, the following particulars, given by Mr. Lyman, on the authority of Mr. Kada, may be quoted:

	$
4 posts	0.100
1 board (6 ft. by 1 ft.)	0.120
12 cross-pieces, $0.96 to $0.216	0.156
Materials for one length (4 ft.) of timbering	0.376
Materials for hut: wood, $1; rushes, $0.63	1.630
1 pair bellows	3.750
1 length of air-pipe (6 ft.)	0.140
1 wheel (two needed for each well)	1.200
1 tank (6 ft. diameter, 6 ft. high)	15.000
1 well bucket	0.500
6 ft. straw rope	0.012
10 soka (? 5000 ft.) small straw rope	0.475
1 pick (large one 16⅝ lbs., small one 6⅝ lbs.)	?
1 rake	0.500
3 rope nets	0.350
1 oil-paper	0.320
1 pot for boiling the labourers' rice or water	0.620

In the locality where these prices prevailed in 1868, the wages of the diggers, not including food, were $0.18¾ per man per day, and of the common labourers, $0.10. One shoo of rice beer (saké) value $0.065 had, however, to be provided for every four men. The number of workmen needed was according to the depth of the well, as follows:

From 1 to 10 fathoms	3 men
„ 10 „ 30 „	4 „
„ 30 „ 40 „	5 „
„ 40 „ 50 „	6 „

The depth of the wells rarely exceeds 50 fathoms.

In the oil-fields of Twingaung and Beme (Yenangyoung district, Upper Burmah), the excavated wells are from four to four and a half feet square. In the former field there is one well of the depth of 310 feet (the greatest depth of a Burmese dug well), and another of 305 feet; the majority of the finished producing wells are, however, not more than 250 feet in depth, the difficulties of getting beyond this depth, on account of the presence of petroleum vapour, and of the "caving" of the sides, being very great. Dr. Noetling divides the producing wells in the Twingaung field into two classes—namely, scarcely productive and productive. The former class do not yield more than 10 viss (1 viss = 3.67 lbs. avoirdupois) per well per diem, on the average. The average yield of the productive wells is not less than 80 to 90 viss per diem. Some of the latter give from 100 to 300 viss per diem, and the daily yield of one is stated to be 500 viss. Over the mouth of the well a cross-beam on uprights is fixed, and in the centre of this is a drum and axle fashioned out of a single piece of wood, and running in naturally grown fork-shaped supports. Over the drum runs a leather rope used to lower or raise the workmen or the earthenware pot (yenanoie) in which the oil is collected. If possible, the well is so situated that the men or women who are drawing up the pot filled with oil, or the digger, walk down the slope of the hill. In excavating the well the earth is loosened by means of a heavy wooden lever, four or five feet in length, three or four inches in diameter at one end, and tapering to the other end, where it is strongly shod with iron. The loosened earth and pieces of rock are brought to the surface in a basket. As the work proceeds the shaft is roughly timbered. The digger is lowered in a rope sling, and as no artificial light can be used in the well owing to the presence of inflammable gas or vapour, his eyes are bandaged before his descent, so that no time may be lost in his becoming accustomed to the comparative darkness

in which he has to work when the well has reached a considerable depth. The presence of petroleum vapour renders breathing difficult, and Dr. Noetling found that the maximum time during which a young and strong man was able to remain at work was 290 seconds.

In Galicia and Roumania dug wells exist; in Moldavia there are stated to be some interesting wells of this description, more than 130 feet in depth, lined with woven sticks.

The most perfectly constructed petroleum wells of the excavated class are those which exist in Italy, at Montechino, Piacenza. They are in some cases no less than 240 feet in depth, by from 8 to 10 feet in diameter, and are described as being perfectly cylindrical, and lined with large bricks firmly cemented together. These wells are stated to have yielded from 160 to 180 lbs. of oil each per day for the past eighty years. The depth of the wells appears to be limited only by the difficulty of working in an atmosphere highly charged with petroleum vapour, several of those employed in the work having lost their lives by suffocation.

The quantity of oil obtainable from a dug well is in all cases comparatively small. Such a well does not usually tap the strata in which the petroleum occurs, and may be regarded as simply affording facilities for the collection of such oil as is brought towards the surface through the action of water percolating through the earth.

XII. The Art of Artesian Well Drilling.

The petroleum well proper is an artesian well, and, as has been stated, the development of the petroleum industry in the United States dates from the sinking of the first oil-well of this description. Artesian well drilling is doubtless an art of considerable antiquity in China, wells being successfully bored to great depths in that country with the simplest appliances, for the purpose of obtaining brine. L'Abbé Huc gives an account of the process adopted, which is worth quoting:—"If there be a depth of three or four feet of soil on the surface, they plant in this a tube of hollow wood, surmounted with a stone, in which an orifice of the desired size of three or four inches has been cut. Upon this they bring to work in the tube a rammer of 300 or 400 lbs. weight, which is notched, and made a little concave above and convex below. A strong man, very lightly dressed, then mounts on a scaffolding, and dances all the morning on a kind of lever that raises this rammer about two feet, and then lets it fall by its own weight. From time to time a few pails of water are thrown into the hole to soften the rock and reduce it to pulp. The rammer is suspended to a rattan cord, not thicker than your finger, but as strong as our ropes of catgut. This cord is fixed to the lever, and a triangular piece of wood is attached to it, by which another man, sitting near, gives it a half turn, so as to make the rammer fall in another direction. At noon this man mounts on the scaffold, and relieves his comrade till the evening, and at night these two are replaced by another pair of workmen. When they have bored three inches, they draw up the tube, with all the matter it is loaded with, by means of a great cylinder, which serves to roll the cord on. In this manner these little wells or tubes are made quite perpendicular [to a depth of from 1500 to 1800 feet, French] and as polished as glass. When the rock is good, the work advances at the rate of two feet in twenty-four hours, so that about three years are required to dig a well."

Artesian well drilling was first practised in Europe in the province of Artois, in France, where such a well exists in the gardens of a former Dominican convent at Lillers, which is stated to have flowed continuously since the year 1126.

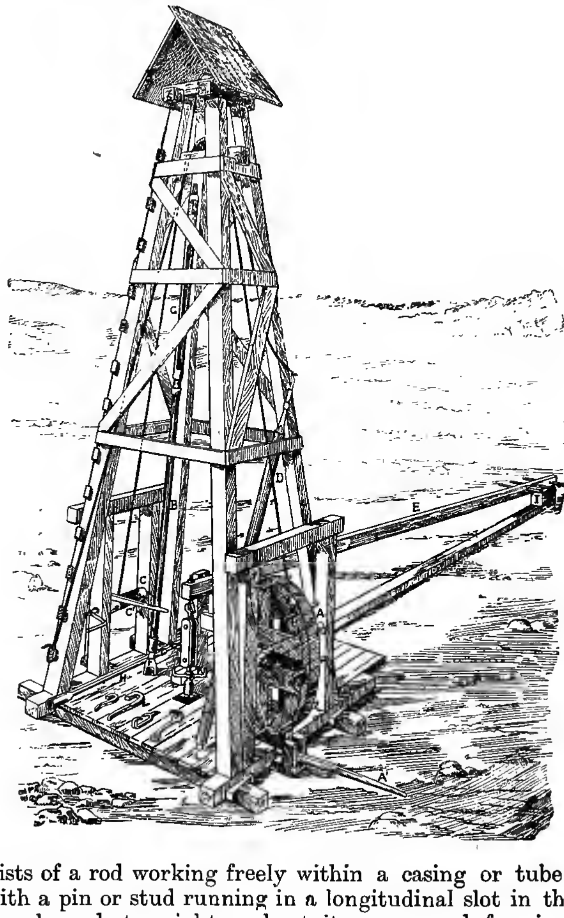
In the United States, the first artesian well was drilled in 1806, with the object of obtaining brine, by the brothers Ruffner. The principal difficulty encountered by these operators was that of preventing the dilution of the brine by the infiltration of surface water. In their first attempt they employed a straight well-formed hollow sycamore-tree, which they sunk in the mire and quicksand in the hope that they might succeed in bedding the lower end on the solid rock. A hard crust was, however, met with at a depth of 13 feet, through which it was found impossible to force the tree trunk, and as the surface water still gained access freely the attempt was abandoned. They then commenced another well at a little distance, using a $3\frac{1}{2}$-inch tube, made by boring lengthwise through a 20-feet oak log, but, again failing, they returned to the first well, and finally succeeded in sinking the "gum," as the hollow tree was termed, through the crust mentioned, to a depth of 16 or 17 feet, when solid rock was reached. Much difficulty was then experienced in making a water-tight connection between the lower end of the "gum" and the rock, but this was finally accomplished by using wooden wedges. The brothers then commenced drilling the rock with a long iron drill, suspended from a "spring-pole," and provided with a $2\frac{1}{2}$-inch chisel-shaped steel bit. Eventually in 1808, after much tedious labour, they completed a hole in the rock of 40 feet in depth, or 58 feet from the upper end of the "gum," and obtained a plentiful supply of brine. It was, however, found necessary to devise some means of preventing the dilution of the brine by infiltration of fresh water which still took place through the upper part of the well, and they accordingly set to work to manufacture two half-tubes out of strips of wood, joining the edges carefully, and binding the halves together with twine. This tube, with a bag of wrapping at the lower end, made to fit as nearly as possible water-tight in the $2\frac{1}{2}$-inch hole, was then driven into the well, and was found to answer its purpose perfectly, the undiluted brine flowing up into the "gum," where a water-tight bottom was constructed to retain it. These particulars are of special interest, since there is the same necessity for preventing the influx of water in the sinking of petroleum wells. Soon afterwards tin tubes, and then copper tubes with screw joints, were substituted for the wooden tubing, and the bag of wrapping was replaced by a more efficient arrangement termed a "seed-bag." This device consisted of a piece of buckskin or calfskin, sewn up like the sleeve of a coat, so as to form a tube some 12 or 15 inches in length, and of about the same diameter as the well. This was slipped over the well-tubing, and the lower end having been securely bound to the tube, was filled to the depth of 6 or 8 inches with flax seed, either alone or mixed with gum tragacanth. The upper end having then, like the lower, been bound to the tubing, but not securely (so that the bag would empty itself if it became needful to draw up the tubing), the arrangement was lowered into the well to the required depth, and the contents of the seed-bag soon swelling by the absorption of water, a water-tight joint was made.

Of the tools devised to facilitate the operation of drilling, none is of greater value than the *jars*. This appliance, which may be likened to a couple of elongated and flattened links of a chain constructed to slide freely the one within the other, was invented in 1831 by William Morris. Its function is to give the drill a sharp jar on the upward stroke, thus loosening the bit if it has become jammed in the rock.

The *spring-pole* employed by the brothers Ruffner consisted of a straight sapling 40 or 50 feet in length, denuded of its branches, and fixed in the ground at an angle of about 30° over the spot where the well was to be drilled. From the upper and smaller end of the tree the drilling tools were suspended, and the requisite movement was imparted by pulling down the end of the sapling, and then allowing it to spring back.

The plant employed in hand-drilling in Galicia is shown in Fig. 76. It consists, as will be seen, of a derrick provided with a powerful windlass A, by means of which a gang of men can draw up the weighty drilling-tools B; a smaller windlass or winch C, for use with the *sand-pump* D, and a long massive beam E (pivoted not far from one end), from which the tools are suspended in the well. The *bit* or drill F is either chisel-shaped, or more often of such a form that it may be described as a combination of the chisel and the gouge. It is attached to an apparatus known as the *free-fall jars*, G,

FIG. 76.



which consists of a rod working freely within a casing or tube; the rod is provided with a pin or stud running in a longitudinal slot in the tube, and this slot is prolonged at a right angle at its upper end, forming a catch for the pin. It is obvious that by slightly turning the rod when it is fully telescoped into the tube, it may thus be held or released. The tools are attached to the beam through the medium of iron rods H, screwed together, which are added successively as the depth of the well increases. Each windlass is provided with a brake A′, C′. It is usual to commence drilling from the bottom of a square shaft excavated as deep as possible, and the operation consists in drawing down the longer portion of the beam until the end strikes against a wooden block I. At this instant the driller gives a slight turn to

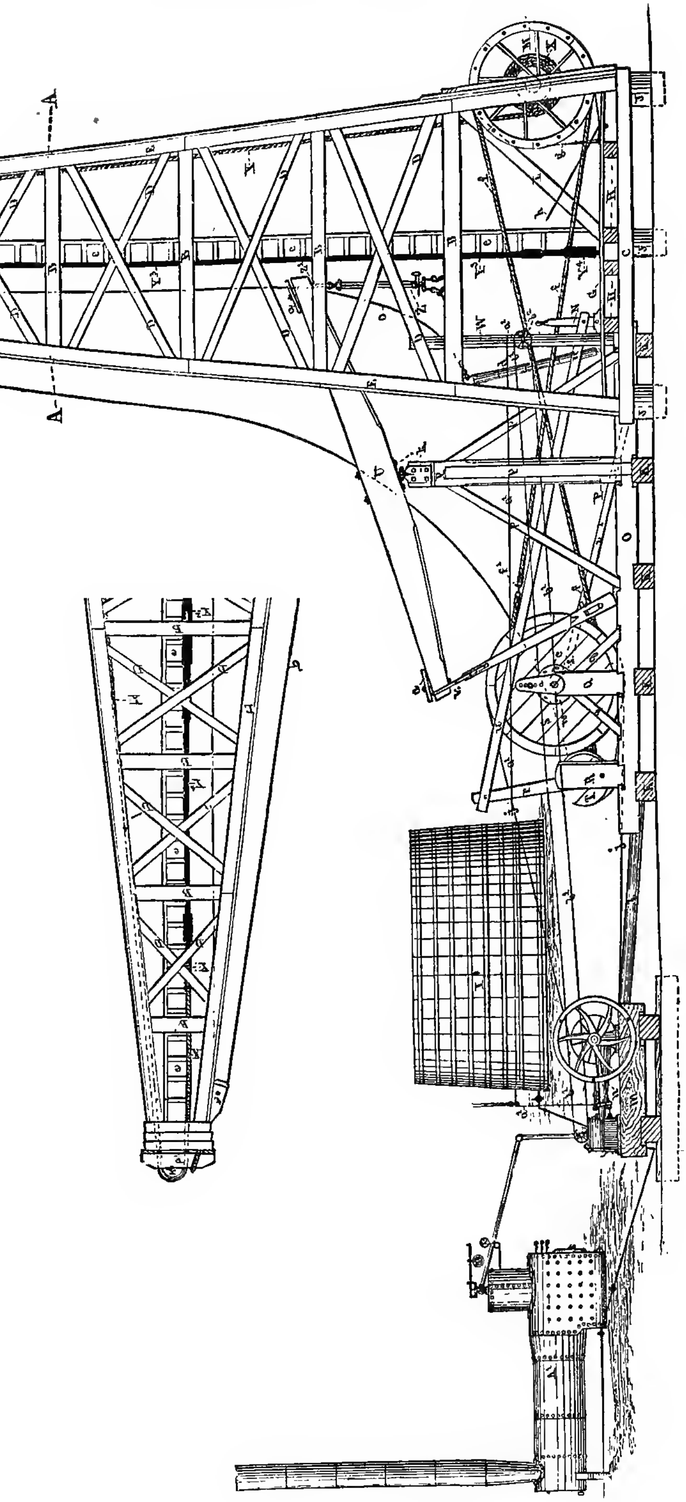
the tools, by means of the lever K, the pin of the jars is released from the catch, and the bit falls a distance of three or four feet, delivering a blow upon the rock at the bottom of the well. The longer end of the beam is then allowed to rise, and the jars being thus telescoped or closed, the driller gives the tools a turn in the reverse direction, and thus again brings the pin into the catch. The beam is usually about 30 feet in length, and pivoted about five feet from one end. A gang of six men is required for the work, in addition to the driller. Drilling by this method is necessarily very slow, the usual number of strokes which the writer has seen delivered per minute being six or seven. Moreover, the maximum weight of the tools capable of being used with a hand-rig is not sufficiently great for expeditious work or deep drilling, and, in fact, very hard strata can scarcely be penetrated with such a system. When the bit requires dressing, or the hole is full of detritus, the drilling tools are drawn up into the derrick by means of a wire rope coiled on the larger windlass, the rods being disconnected one by one. The well is then cleared out with the sand-pump D, which is a cylinder provided at the lower end with a valve opening inwards. The sand-pump is lowered into the well by the use of the smaller windlass, and when it reaches the bottom, the valve is pushed open by the projecting stem L, and the mud flows in. As the cylinder is raised, the valve, of course, closes.

Horse power and steam-power were employed in drilling wells for brine in the United States before the drilling of the first petroleum well in that country.

XIII. The Production, Transportation, and Storage of Crude Petroleum in the United States.

The first operation connected with the drilling of a petroleum well is the construction of the *derrick* (Figs. 77 and 78, pp. 140 and 141). This structure is pyramidal in form, and consists of four strong timber uprights held in position by the necessary ties and diagonal braces, and resting on stout wooden sills. The height of the derrick is determined by the depth of the well, or, more strictly speaking, by the length of the "string" of drilling tools. In districts where the wells are comparatively shallow, lighter and shorter strings of tools can be employed, and here the derrick is not more than 30 feet in height, but in drilling to the considerable depth necessary in the principal oil-fields of the United States, where the oil-bearing rock lies at a depth of a couple of thousand feet or more beneath the surface, long and heavy strings of tools have to be used, and here the derrick is at least 70 feet, and sometimes more, in height, by about 20 feet square at the base, and 4 feet square at the summit. The corner timbers of the derrick are formed of two 2-inch planks spiked together at right angles, and are added in successive lengths as the structure is built up story by story. Surmounting the derrick and holding the upper ends of the four corner posts firmly in position is the *crown-block* of massive timber. The floor of the derrick slopes slightly downwards from the centre, and the lower part of the structure is boarded in and roofed. Up one side of the derrick, a ladder leads from the base to the summit. Immediately outside the derrick on the strong wooden foundation stands the *Samson-post*, a massive square pillar of wood, which carries the *walking-beam*. Inside the derrick is a smaller upright, termed the *headache-post* or *life-preserver*, to support the end of the walking-beam when disconnected. The end of this beam outside the derrick is connected by means of a rod termed the *pitman*, with a crank attached to the axle of the *band-wheel*. This wheel runs in bearings on a couple of uprights, and is caused to revolve through the medium of a band driven by a steam-engine in an adjoining shed, a rocking movement being thus imparted to the walking-beam. The

FIG. 77.

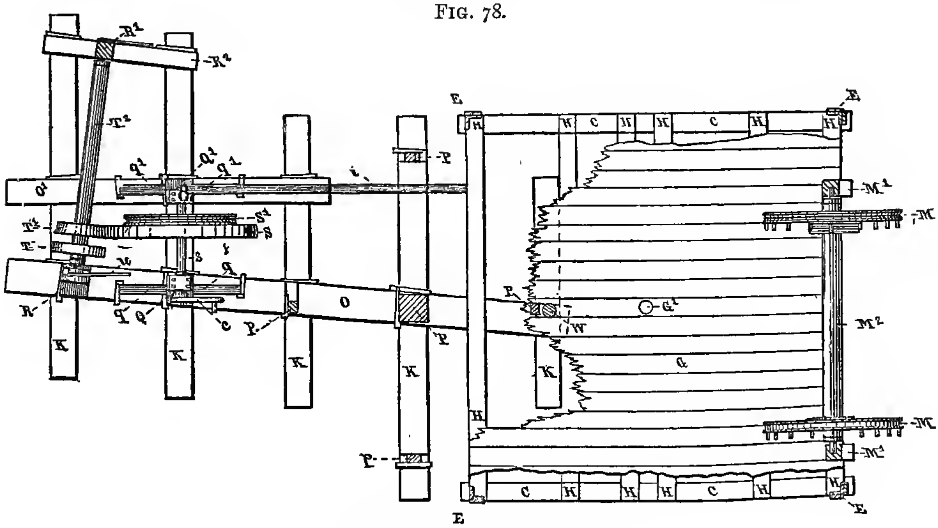


Complete Outfit ready for drilling a well. Side elevation.

LETTERS OF REFERENCE TO FIG. 77.

A Derrick.
A^1 Boiler.
B Derrick girth.
C Derrick sill.
D Brace.
E Derrick corner.
F Crown pulley block.
G Derrick floor.
H Derrick floor sill.
I Water tank.
J Foundation post.
K Mud sill.
L Brace from back bull-wheel post.
M Bull-wheel.
N Sand-reel lever handle.
O Main sill
P Samson post.
Q Front jack-post.
R Knuckle post for sand-reel.
S Band wheel.
T Sand-reel friction pulley.
U Walking beam.
V Pitman.
W Headache, or Deadhead post.
X Drilling cable.
Y Rope socket.
Y^1 Sinker bar.
Y^2 Jars.
Y^3 Auger stem.
Y^4 Bit.
Z Temper screw.
Z^1 Drilling hook.
a Adjuster board.
a^1 Reverse cord to engine link.
a^2 Pulley for reverse cord, a^1.
b Sand-pump line.
b^1 "Telegraph" to control engine.
b^2 "Telegraph" pulley.
c Band wheel crank.
d Bailer, or Sand pump.
e Derrick ladder.
f Bull rope.
f^1 Bull rope couplings.
g Bull wheel brake band.
h Brake lever.
i Brace of back jack-post, Q^1.
j Engine belt.
k Centre irons.
l Brace of engine block, m.
m Engine block.
n Engine.
p Samson post brace.
q Jack post brace.
r Sand-reel lever.
s Band-wheel shaft.
t Sand-pump pulley block.
u Sand-reel draw bar.
v Pitman stirrup.
x Crown pulley.

FIG. 78.



Ground Plan of Drilling Rig.

LETTERS OF REFERENCE.

C Derrick sill.
E Derrick corner.
G Derrick floor.
G^1 Well hole.
H Derrick floor sill.
K Mud sill.
M Bull-wheel.
M^1 Bull-wheel post.
M^2 Bull-wheel shaft.
O Main sill.
O^1 Sub, or Counter sill.
P Samson post.
Q Front jack-post.
Q^1 Back jack-post.
R Knuckle post.
R^1 Sand-reel back post, or Tail piece.
R^2 Tail sill.
S Band wheel.
S^1 Tug pulley.
T Sand-reel brake pulley.
T^1 Sand-reel friction pulley.
T^2 Sand-reel shaft.
W Headache, or Deadhead post.
c Band-wheel crank.
i Brace of back jack-post, Q^1.
p Samson-post brace.
g Brace of front jack-post, Q.
g^1 Brace of back jack-post, Q^1.
s Band-wheel shaft.
u Sand-reel draw bar.

steam-engine is of the horizontal pattern, and from 12 to 15 h.p. The boiler is of the locomotive type, and is usually fired with natural gas. To the side of the derrick opposite the Samson-post are fixed the bearings of the *bull-wheel*, a wooden windlass of massive construction, used for lowering and raising the drilling tools. The bull-wheel is driven by the *bull-rope*, a 2-inch plain-laid cable, joined by iron couplings, which runs, crossed, in grooves in the bull-wheel and in the *drive-wheel* on the band-wheel shaft. The bull-wheel is provided with a powerful band-brake. A second windlass, termed the *sand-reel*, is also provided. This windlass, which is much smaller, is used for raising the detritus and water from the well. It is fixed close to the band-wheel, and one of its supports is pivoted to the foundation of the derrick. Attached to this support is a rod which passes into the derrick, where it is connected with a vertical lever. By pulling this lever the slightly conical wheel on the sand-reel shaft is brought into contact with the band-wheel, and thus has motion imparted to it by friction. The driller can thus, from the mouth of the well, start or stop the revolution of the sand-reel. An endless cord, termed the *telegraph*, passes round a pulley on the throttle-valve of the engine, and a similar pulley in the derrick; the reversing link is also operated by a cord from the derrick; the running of the engine can thus be controlled from the interior of the derrick. The bull-wheel being driven through the medium of the band-wheel, the pitman which gives motion to the rocking-beam is disconnected when the bull-wheel is used, and similarly the bull-rope is thrown off when the pitman is in use. The cable used to support the drilling tools is a 6-inch (2 inches in diameter) untarred Manilla rope, It passes from the great windlass over a grooved wheel termed the *crown-pulley*, fixed in the crown-block at the summit of the derrick, and thence to the drilling tools. The following are the particulars of the *string of tools* employed (see Figs. 77 and 79).

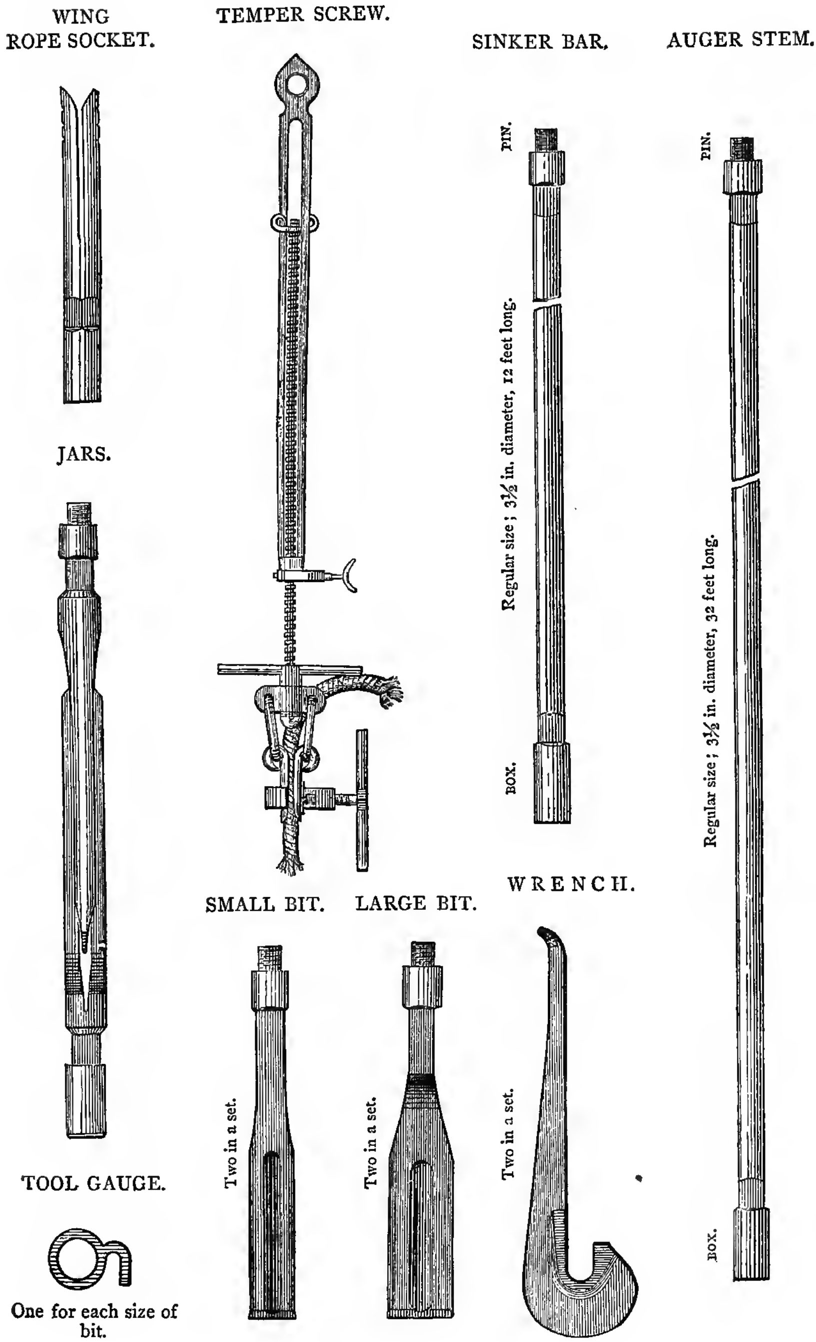
	Length. Ft. In.	Weight. lbs.
Rope-socket	3.0	90
Sinker-bar	12.0	400
Jars	6.0	300
Auger stem	32.0	1050
Bit	3.4	140
	56.4	1980

These particulars are taken from the catalogue of the Oil Well Supply Company, of Bradford and Oil City, Pa., dated 1884. Mr. Carll gives the length of a string of tools as 62 ft. 1 in. and the total weight as 2100 lbs., the chief difference being in the length and weight of the sinker-bar. Still heavier strings of tools are now employed. The sinker-bar and auger stem are of round Norway iron, about 4 inches in diameter. The bits are faced with steel and range in width from about 4½ inches to more than a foot, by about 4 inches in thickness. The various component parts of the string of tools are connected by conical male and female screws, the ends being squared for the application of a pair of powerful *wrenches*, Fig. 79. The tools are connected in the order in which they are given in the table, and the end of the drilling cable is held by the rope-socket.

The *jars* practically divide the string of tools into two sections, the one delivering a blow downwards and the other a blow upwards. The *auger* or drill, which cuts and pulverises the rock, consists of the *bit*, or cutting tool, the *auger stem*, to provide the necessary weight, and the lower link of the jars. The *sinker-bar* and upper link of the jars provide the necessary momentum for delivering an upward blow on the inside of the lower link of the jars to loosen the drill in case it is jammed in the rock by the down-stroke.

Fig. 79.

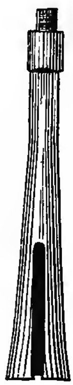
SET OF DRILLING TOOLS.



The necessary outfit includes, besides bits of various sizes, *reamers*, Fig. 80, to enlarge the bore of the well; *winged substitute*, Fig. 81, placed above the bit to keep it from glancing off; larger jars, *temper-screw*, and *clamps*, Fig. 79, wrenches (already referred to), *sand-pumps*, Fig. 82, to remove the detritus, and *bailer*, Fig. 82, to remove water from the well. The temper-screw hangs from a hook on the end of the walking-beam over the mouth of the well, and its function is to provide for the gradual lowering of the tools as the drilling proceeds. At the lower end of the temper-screw are the

Fig. 80.

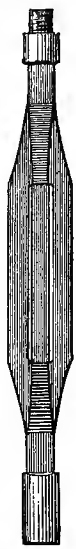
ROUND REAMER.



To straighten a crooked hole.

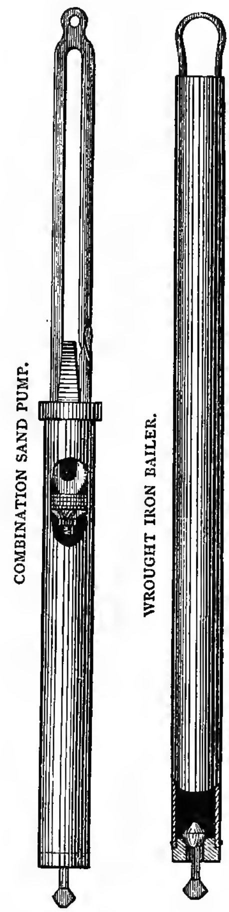
Fig. 81.

WINGED SUBSTITUTE.



Sometimes placed just above the bit to keep it from glancing off, also above the round reamer to keep it to its place.

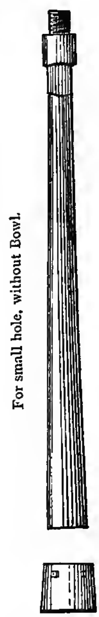
Fig. 82.



clamps, which can be screwed together so as to grasp the drilling cable at the required point. The sand-pump often consists simply of a plain cylinder of galvanised iron, as shown in the bailer, Fig. 82, usually about 6 feet in length, but sometimes considerably more, provided at the bottom with a valve opening inwards. The valve is furnished with a stem projecting downwards, so that when the empty cylinder is lowered to the bottom of the well, or the cylinder, after becoming filled with water and pulverised rock, is withdrawn from the well and lowered into a trough, the valve is pushed open. In the former case, the opening of the valve admits of the entrance of the detritus, the valve closing by gravitation as the cylinder is raised; in the

latter case, the opening of the valve allows of the escape of the material removed from the well. Another form of sand-pump has, in addition to the bottom valve, a plunger attached to an iron rod passing through a stirrup spanning the top of the cylinder, as shown in Fig. 82. The apparatus is suspended from the upper end of the plunger rod, and when it reaches the bottom of the well, the slackening of the rope allows the plunger to descend to the bottom of the cylinder; on tightening the rope, the plunger is first raised, the entrance of the detritus being thus facilitated, and when the plunger has reached the stirrup the cylinder itself begins to rise. The rope to which the sand-pump is attached passes over a small pulley at the top of the derrick and thence to the sand-reel. The bailer is similar in construction to the simpler form of sand-pump, but is much longer, and is employed, as its name indicates, to remove water or oil from the well.

FIG. 83.
HORN SOCKET,
With or without ADJUSTABLE BOWL.



Adjustable Bowl for large hole.
To take hold of any loose tools in the well.

Besides the drilling tools enumerated, a number of appliances termed *fishing tools*, Figs. 83 to 87, have to be provided. Of these there are hundreds, if not thousands, of forms, and considerable ingenuity has been expended in devising them. (The uses of those figured are described in the notes appended.) By means of the ponderous *pole-tools*, which are screwed together length by length, until an iron rod of sufficient length to reach to the bottom of the well, and weighing many tons, is formed, it is possible, at a depth even of, say, 1500 feet, after having cut off a broken cable from the rope socket, to unscrew a string of tools and raise the component parts one by one, or even to cut a thread on the end of a fractured sinker-bar or auger-stem, and thus obtain, by screwing, a firm hold of the tool, so that it can be brought to the surface. Among the other instruments are the various *grabs* (Figs. 84–86), some of which are designed to pick up any small object that may have been lost in the well, such as a valve cup.

Before proceeding to describe in detail the operation of drilling a well it will be advantageous to consider the arrangements usually made in the United States in obtaining a site for the well. The development of the oil territory in Pennsylvania and New York has shown that the producing fields lie on what is termed the *45° line*, which is a line running north-east and south-west, and accordingly, in the extension of territory, preference is usually given to sites lying on a line drawn in this direction through existing productive wells. It is also considered by some that a well which enters the oil-bearing rock at a synclinal is likely to yield more largely than a well which taps the same rock at an anticlinal. Drilling on a hillside or on the summit of a hill is not found to have any disadvantage, as compared with drilling in a valley, other than that which attaches to the circumstance that the oil-sand may lie at a greater distance from the surface in the former case. Wells drilled in untried territory, or at a considerable distance from other wells, are termed *wild-cat* wells. The cost of drilling being considerable, and the risk of getting a *dry hole*, or unproductive well, being in some districts by no means slight, the production of petroleum is usually, but by no means invariably, carried out by a company rather than by an individual. A promising site having been selected, the land is occasionally purchased outright, but more commonly it is leased, the owner receiving, it may be, $100 or $150, or more, per acre,

FIG. 84.

FISHING TOOLS.

ROPE SPEAR.

To catch end of the rope when it has parted in the well.

TWO WING ROPE GRAB.

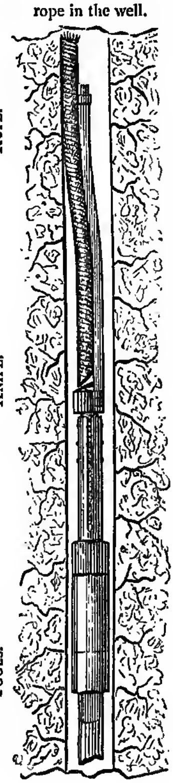
THREE WING ROPE GRAB.

To take hold of the rope when it is broken off in the well.

SUCKER ROD JARS.

To attach to sucker rods for cutting rope in the well.

Showing rope knife cutting off rope in the well.



VALVE ROPE KNIFE.

Used on a string of sucker rods.

ADJUSTABLE ROPE KNIFE.

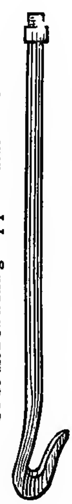
To be used on a string of sucker rods.

V ROPE KNIFE.

To be used on a string of sucker rods.

HOOK ROPE KNIFE.

To be used on a string of pipe or sucker rods.



To cut the rope when the tools are fast in the well.

FIG. 85.

FISHING TOOLS.

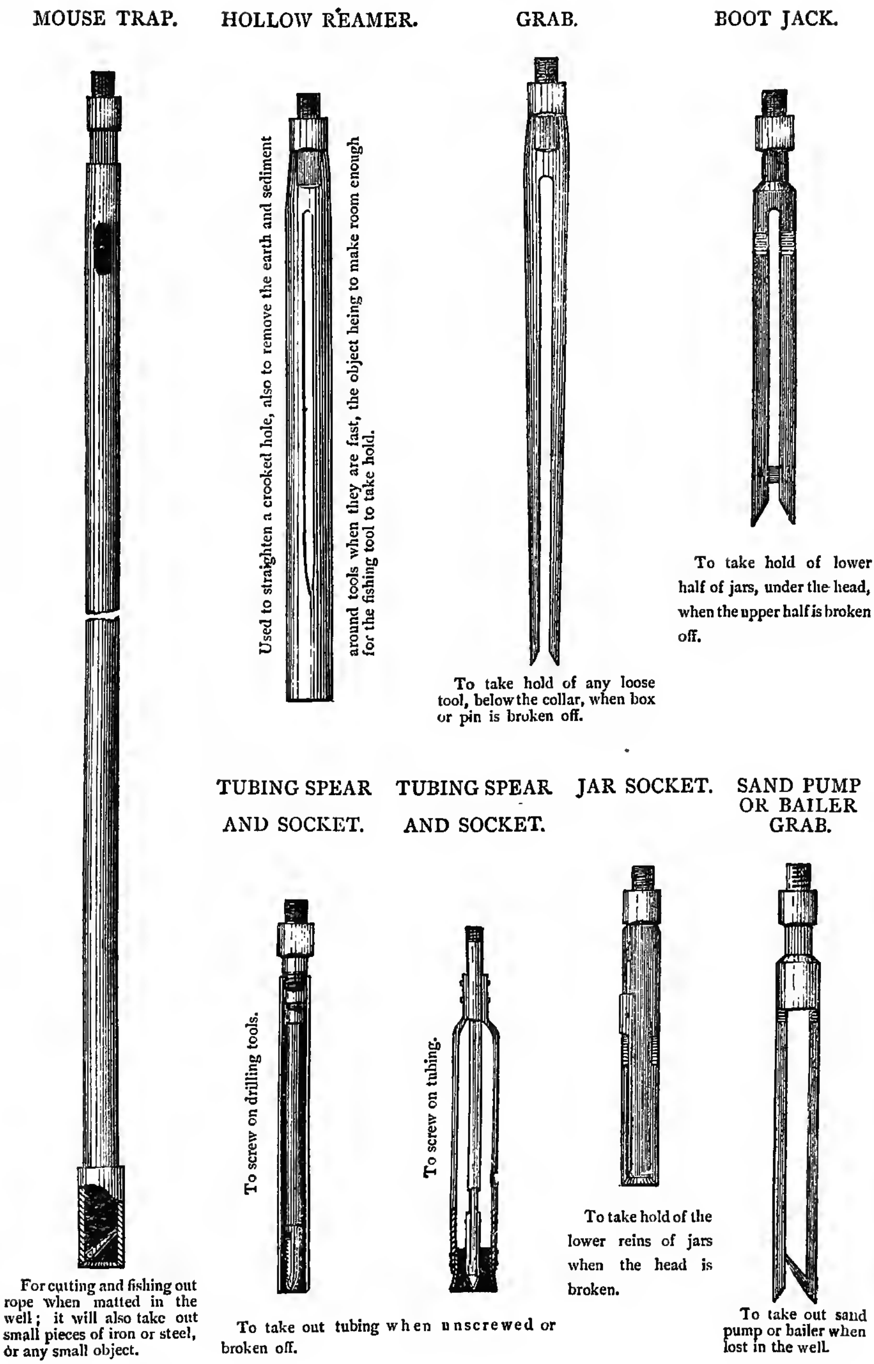
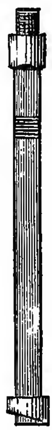


FIG. 86.

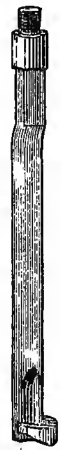
FISHING TOOLS.

HOOKS FOR STRAIGHTENING BIT OR REAMER.

FRONT.



SIDE.



To straighten a bit or reamer lost in the well when it lies against or has been jammed in the well—the hook goes round the shank.

ALLIGATOR GRAB.

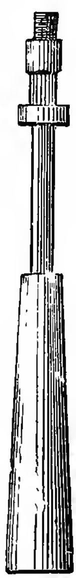
To take hold of a piece of steel or other small article that has been lost in the well.

RASP.

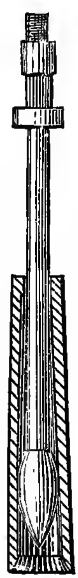
TWO WINGS.

For rasping or reducing the size of a box or collar on lost tools, so that fishing tool can take hold.

MANDREL SOCKET.

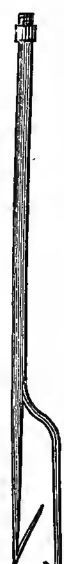


SECTION OF MANDREL SOCKET.



To take hold of casing that has collapsed or become broken in the well.

GRAB FOR PACKER RUBBER.



To take out rubber that has come off of the packer.

and a certain proportion (one-eighth or more) of the oil produced. The drilling is commonly done by contract, the producer putting up the derrick and furnishing the engine and boiler, while the drilling contractor finds the tools and takes all risks of accident or failure to complete the well. The drilling *crew* consists of two *drillers* and two *tool-dressers*, working in pairs in two *tours* (noon to midnight and midnight to noon).

The first step in the drilling of a well is to sink a *conductor* through the surface ground to the solid *bed-rock*. When the superficial clays and gravels

FIG. 87.

FISHING TOOLS.

TWIST DRILL.

When the top of a lost tool has been battered down so large that it fills the hole, and there is not room for a fishing tool to take hold, this drills a hole in the top in which is inserted the Twist Drill Spear. Used on tubing.

TWIST DRILL SPEAR.

To catch a lost tool after the Twist Drill has made a hole. Used on tools.

VALVE CUP GRAB.

To take out valve cups when they have dropped from the valve.

ROPE WORM.

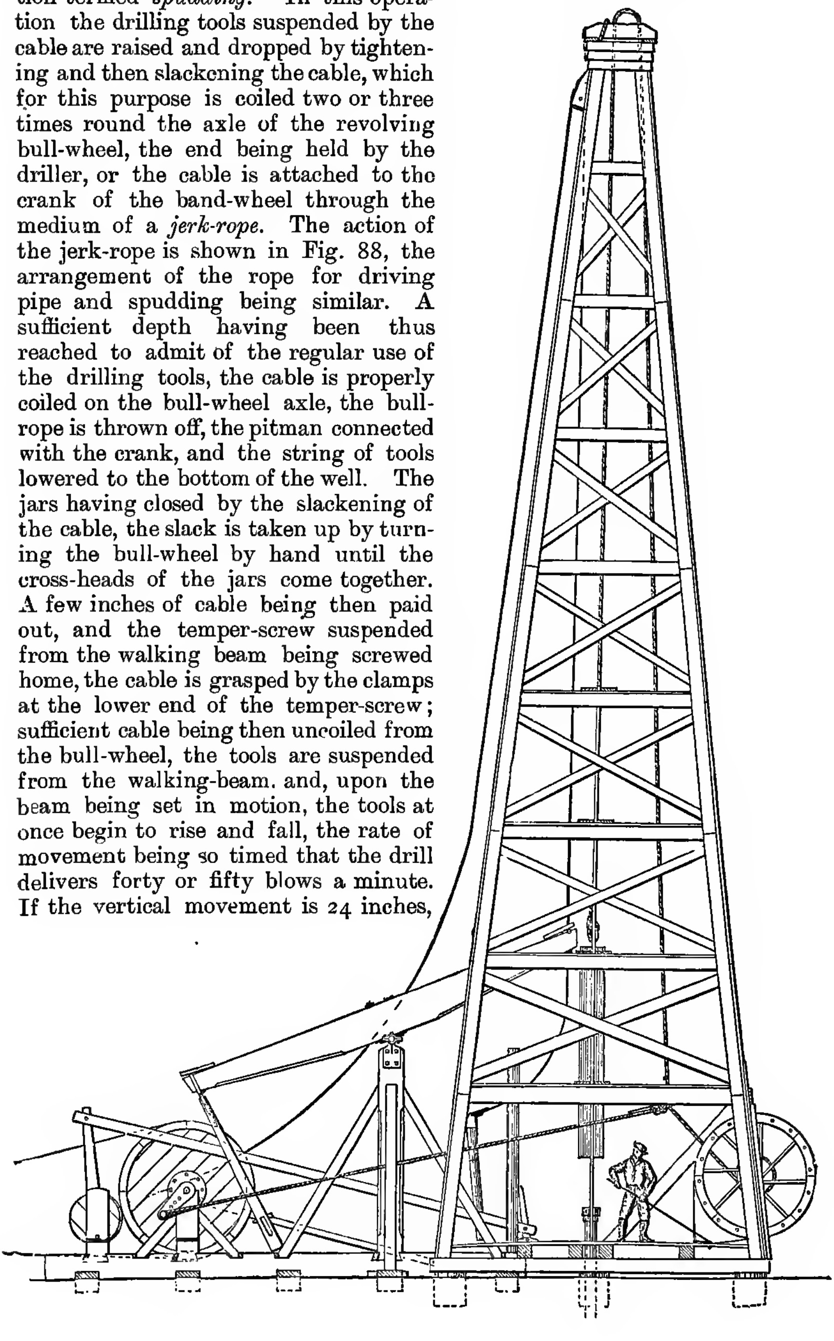
To take rope out of tubing.

are not more than 10 or 15 feet in thickness, a common well-shaft, 8 or 10 feet square, is dug to the rock, and a wooden conductor, somewhat greater in internal diameter than the proposed bore of the upper part of the well, is placed so as to extend from the surface of the rock to the floor of the derrick, the junction between the conductor and the rock being carefully made with a view of excluding gravel and mud from the well. When the depth of surface-ground is too great to admit of digging down to the rock, strong iron piping, termed *drive-pipe*, furnished at the lower end with a sharp-edged *shoe*, is forced down by means of a mall working in guides, as in pile-driving, Fig. 88. When 200 or 300 feet have to be thus driven, as is sometimes the case, the preservation of a vertical line demands a good deal of skill. If the bed-rock is reached at a less distance than about 60 feet from the surface,

the drilling tools cannot at first be used in the ordinary manner, and the drilling has then to be commenced by the operation termed *spudding*. In this operation the drilling tools suspended by the cable are raised and dropped by tightening and then slackening the cable, which for this purpose is coiled two or three times round the axle of the revolving bull-wheel, the end being held by the driller, or the cable is attached to the crank of the band-wheel through the medium of a *jerk-rope*. The action of the jerk-rope is shown in Fig. 88, the arrangement of the rope for driving pipe and spudding being similar. A sufficient depth having been thus reached to admit of the regular use of the drilling tools, the cable is properly coiled on the bull-wheel axle, the bull-rope is thrown off, the pitman connected with the crank, and the string of tools lowered to the bottom of the well. The jars having closed by the slackening of the cable, the slack is taken up by turning the bull-wheel by hand until the cross-heads of the jars come together. A few inches of cable being then paid out, and the temper-screw suspended from the walking beam being screwed home, the cable is grasped by the clamps at the lower end of the temper-screw; sufficient cable being then uncoiled from the bull-wheel, the tools are suspended from the walking-beam. and, upon the beam being set in motion, the tools at once begin to rise and fall, the rate of movement being so timed that the drill delivers forty or fifty blows a minute. If the vertical movement is 24 inches,

FIG. 88.

DRIVING PIPE.



the sinker-bar first moves, say, four inches on the up-stroke, the cross heads of the jars come together with a sharp blow, and the auger-stem is lifted 20 inches. On the down-stroke the drill falls 20 inches, and delivers its blow upon the rock at the bottom of the well, while the sinker-bar goes down 24 inches to telescope the jars. An unskilful driller sometimes closes the jars, this being especially liable to occur if the well is deep and contains much water, and thus works for hours without accomplishing anything, for the tools may be resting on the bottom or remain suspended; but an expert can tell, by grasping the cable, whether the drill is working properly or not. As the "jar" grows feeble, it is "tempered" to the requisite strength by slightly lowering the temper-screw, which practically lets out a little more cable. Some of the best drillers, however, work by the spring of the cable alone when a sufficient depth has been reached, and only use the jars when the drill jams. This operation is termed "bouncing the drill." As the drilling proceeds, the driller, who has his hand on the temper-screw lever, gives the cable a slight twist, and thus causes the chisel end of the bit to do its work evenly over the entire surface of the bottom of the well. When the whole length of the temper-screw has been let out, or the bit requires dressing, the engine is stopped, the bull-wheel connected, the pitman detached from the crank, and the tools drawn up into the derrick, so that the lower end of the drill is above the level of the floor. The wrenches are then applied, the bit is unscrewed, and a fresh bit attached. The dressing of the bit consists in heating the cutting end in the forge fire, and hammering it out to a blunt edge of the required width. The principal object of the dressing is to preserve the necessary width, for this width determines the diameter of the well. The writer has seen a bit diminished in width to the extent of half an inch during its use in the pulverising of a very few feet of hard rock, while the cutting edge was not greatly blunted. Before the tools are again lowered, the sand-pump is used to remove the detritus from the well, and the hole having thus been cleared, the brake is released and the tools allowed to run down. If the well has reached a considerable depth, the velocity with which the tools descend is such that the massive derrick vibrates to its foundations, but the driller, with his hand on the brake and carefully watching for a piece of string tied round the cable at the required point, reduces the speed before the tools reach the bottom. The cable having been, as before, grasped by the clamps (the temper-screw having been again screwed home), the pitman is connected, the bull-rope thrown off, and drilling recommenced. At night, the derrick is lighted with a primitive form of lamp, which may be likened to an iron kettle with a spout on each side, in which crude petroleum is burned. In winter the derrick is frequently warmed by a simple stove, consisting of a cylinder of sheet iron, in which natural gas is burned.

When natural gas is obtained in sufficient quantity to furnish fuel for the boiler, it is conducted from the well through a 2-in. pipe, connected with the casing, and passing into the fire-box. A $\frac{1}{4}$-in. steam-pipe, fitted with an elbow and $\frac{1}{8}$-in. jet, is inserted in the gas-pipe close to the fire-box, and a current of steam is thus caused to issue with the gas. This apparatus acts as an exhauster, drawing the gas from the well, and preventing the flame from running back.

The operation of drilling is, as already stated, continued day and night, but seldom proceeds very long without the occurrence of some accident which necessitates the use of fishing-tools. Sometimes it happens that the fishing operation is unsuccessful, and after months of labour the well has to be abandoned with a string of tools in the hole. In rare instances, after ineffectual attempts to raise tools which have become detached, it has been found possible to drill past them. The time occupied in drilling to a depth

of 1700 feet, the nature of the accidents which may occur, and the extent of the delays thus occasioned, are shown in the following record relating to a well drilled in the Bradford field :—

Dennis Well, No. 1,

situated on the Rogers Farm, ¾ mile S., 25° W., of Bradford, McKean Co., Pa.

			Daily Advanced, Feet.		Depth, Feet.
1877.					
Nov.	29	Conductor 21 ft. previously set	12	to	33
„	30	Thawing supply pipes	—		—
Dec.	1	Pulling tubing from water well	—		—
„	2	(Sunday)	—		—
„	3		34	„	67
„	4		48	„	115
„	5		60	„	175
„	6		35	„	210
„	7		50	„	260
„	8	Engine gives out	31	„	291
„	9	(Sunday)	—		—
„	10		49	„	390
„	11		45	„	435
„	12	Putting in casing	10	„	445
„	13		10	„	546
„	14		86	„	632
„	15		66	„	698
„	16	(Sunday)	—		—
„	17		72	„	770
„	18		68	„	838
„	19		81	„	919
„	20		34	„	953
„	21		34	„	987
„	22		34	„	1021
„	23	(Sunday)	—		—
„	24	Broke jars and lost tools at 1056 ft.	35	„	1056
„	25	(Christmas)	—		—
„	26	Fishing	—		—
„	27	Fishing	—		—
„	28	Fishing, got tools out, *minus* bit	—		—
„	29	Fishing	—		—
„	30	(Sunday)	—		—
„	31	Fishing	—		—
1878.					
Jan.	1	Fishing. Pin broke above jars	—		—
„	2	Fishing	—		—
„	3	Cleared the hole	7	„	1063
„	4		7	„	1070
„	5		15	„	1085
„	6	(Sunday)	—		—
„	7		15	„	1100
„	8		16	„	1116
„	9		9	„	1125
„	10		19	„	1144
„	11		31	„	1175
„	12		39	„	1214
„	13	(Sunday)	—		—
„	14		40	„	1254
„	15		33	„	1287
„	16		40	„	1317
„	17		29	„	1346
„	18		55	„	1401
„	19		49	„	1450
„	20	(Sunday)	—		—
„	21		27	„	1477
„	22		38	„	1515
„	23		35	„	1550
„	24	Bull-wheel broke down	12	„	1562

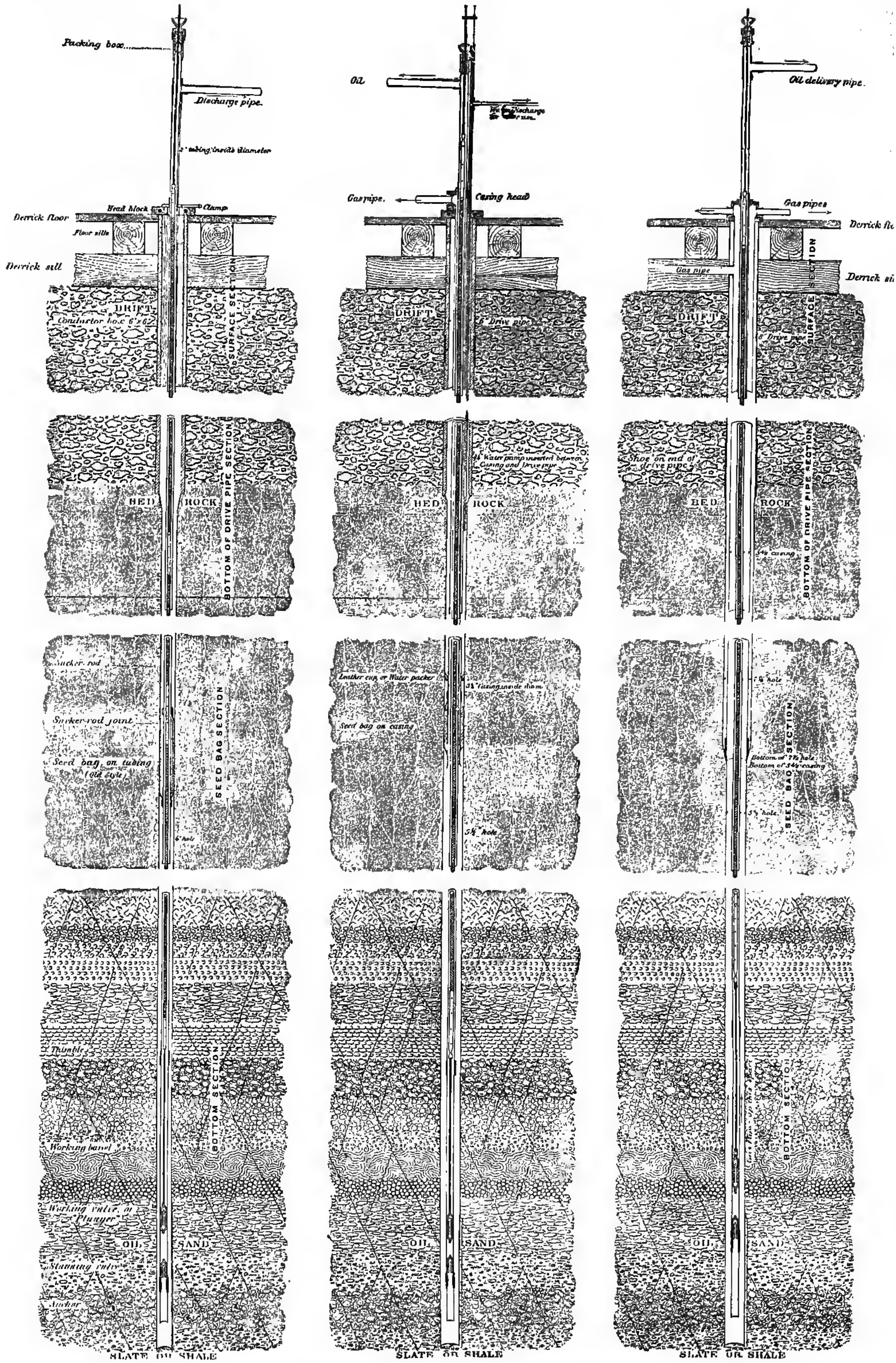
1878.		Daily Advanced, Feet.		Depth, Feet.
Jan. 25	. . . .	21	to	1583
„ 26	Cable parted 9.30 p.m., tools and 1400 ft. of rope in hole	62	„	1645
„ 27	(Sunday)	—		—
„ 28	Fishing	—		—
„ 29	. . . .	17	„	1662
„ 30	Struck the oil sand at 1664 ft.	9	„	1671
„ 31	. . . .	14	„	1685
Feb. 1	. . . .	14	„	1699
„ 2	. . . .	20	„	1719

Total time of drilling, about 47 days—66 days from time drilling began to completion of well. Average progress, about 36½ ft. per day. Best 24 hours' work, 101 ft. Well drilled dry; cased at 435 ft. Torpedoed on completion, when it gave a heavy flow of oil for a short time, and afterwards yielded about 35 barrels per day.

It will be observed that the well in question was increased in depth 55 ft. after the oil-sand had been reached. It is usual thus to drill into the oil-bearing rock with the object of obtaining a considerable extent of surface for the outflow of oil into the well. During this operation the oil frequently flows from the well mouth, and in order to prevent loss, the drilling is carried on through an *oil-saver*, which is a cap fitted to the casing of the well and provided with a lateral pipe through which the oil can pass to a receptacle.

Every well in Pennsylvania is naturally divisible into three sections, viz.: (1) surface clays and gravels, (2) stratified rocks containing more or less water, (3) stratified rocks seldom water-bearing, including the oil-sands. The first division requires the conductor already described, and the second division requires casing to shut off the water from the third section. The earlier method of excluding the water, by placing a seed-bag round the tubing, has already been mentioned. This method was found unsatisfactory, as the tubing could not be removed for repairs without disturbing the seed-bag, and letting water into the well. In 1868, cast-iron drive pipe was adopted as a substitute for the wooden conductor used in the earlier wells. The most important alteration made in 1868 was, however, the introduction of $3\frac{1}{4}$-in. *casing* as a permanent fixture. This casing extended to the bottom of the water-bearing rocks, and was furnished either with the seed-bag or with a leather cup, which was forced open against the sides of the well by the pressure of the water. Tubing of 2 in. diameter, and extending nearly to the bottom of the well, was then placed inside and suspended from the casing. To obtain a supply of water for the boiler, a small pipe was inserted between the casing and the drive-pipe, into the water chamber above the seed-bag. Although the 1868 well was a great improvement on the earlier wells, it possessed defects. Thus, the casing being $3\frac{1}{4}$-in. internal diameter, while the uncased part below it was $5\frac{1}{2}$-in., fishing tools could not be easily introduced, and if it became necessary to deepen the well, only a $3\frac{1}{8}$-in. bit could be used. The improvements which followed are best exemplified by the description of one of the wells of 1878. This well has an 8-in. wrought-iron drive pipe, armed at the bottom with a steel shoe. The pipe is driven down to the bed rock, and an 8-in., or, strictly speaking, $7\frac{7}{8}$-in., hole is drilled to the base of the water-bearing strata. At this point the bore is reduced to $5\frac{5}{8}$-in., and there a bevelled shoulder is made in the rock; $5\frac{5}{8}$-in. artesian casing, provided at the lower end with a collar to fit the bevelled shoulder, is then inserted, and a sufficiently water-tight joint is thus made. Drilling with $5\frac{1}{2}$-in. bits is then continued until the required depth has been reached. This system admitted of the drilling of the well with only sufficient water in the bore for sand pumping, the water being shut off as soon as the $5\frac{5}{8}$-in.

FIG. 89.

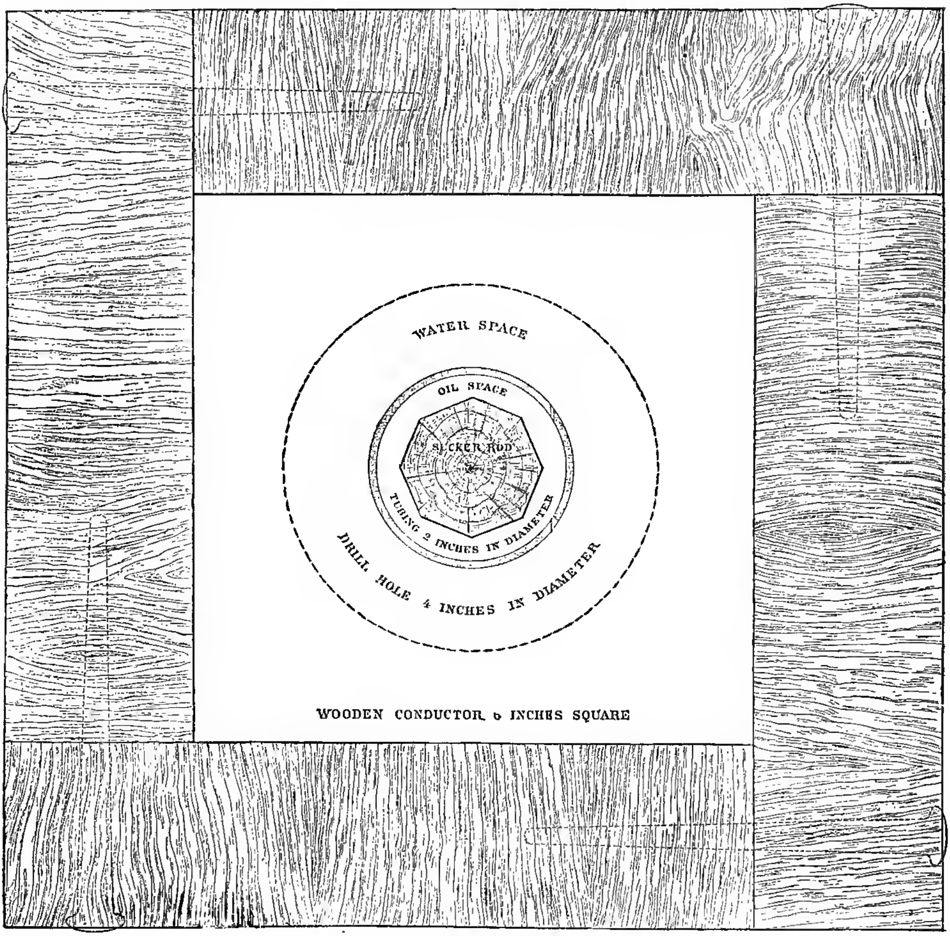


1861. 1868. 1878.

Sectional drawings of three Oil Wells in Pennsylvania, showing successive variations in style of drill-hole. drive-pipe, seed-bag, tubing and casing, from 1861 to 1878.

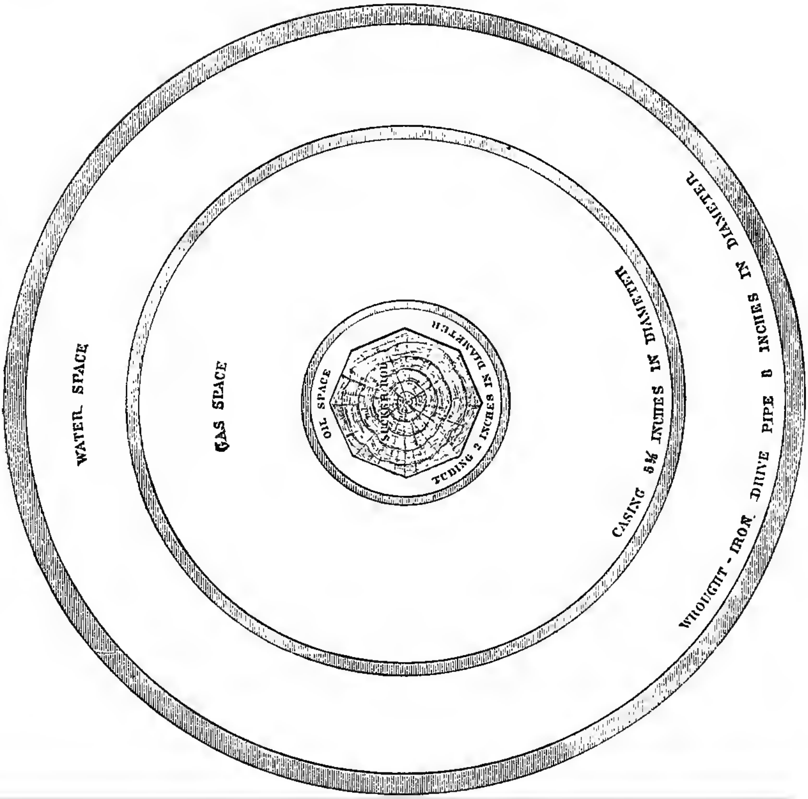
casing was introduced, while the 1868 system necessitated the completion of the well before the introduction of the casing, and therefore the well had to be drilled in water, the buoyancy of which interfered with the action of the drill. The characteristic features of the three systems are shown in Figs. 89, 90, and 91. The casing, consisting of strong wrought-iron lap-welded tubing, is added in successive lengths screwed together.

FIG. 90.



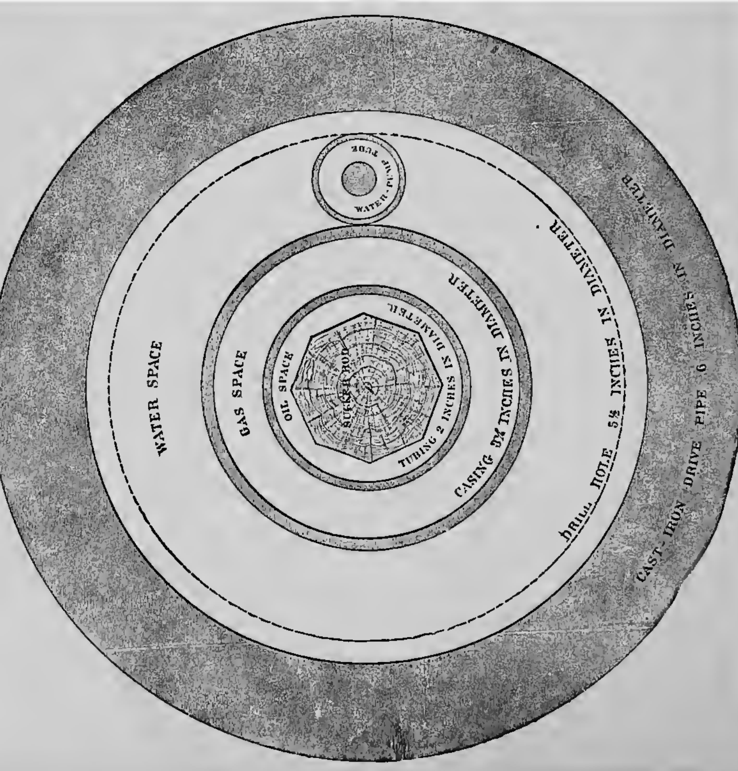
Cross section of Well of 1861.

The depth of the wells increased from 436 feet in 1861 to 1606 feet, or more, in 1878, Fig. 92. The time occupied in the drilling of a well of given depth is, of course, largely dependent on the character of the strata. The variations which may occur are shown in Fig. 93 (p. 158). In the Washington field the average depth of the wells is about 2400 feet, but when the writer visited that field in 1886 he was informed that there was a producing well of the depth of 2595 feet, and it is stated that there is an unproductive well, or "dry hole," which has been carried to the depth of 4303 feet. Only the



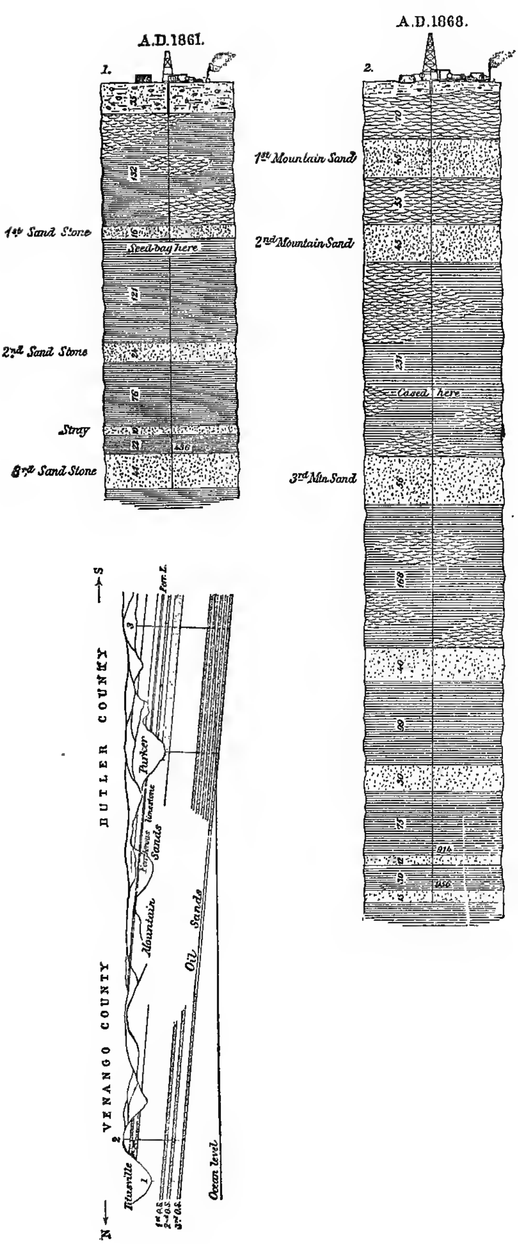
Cross section of Well of 1878

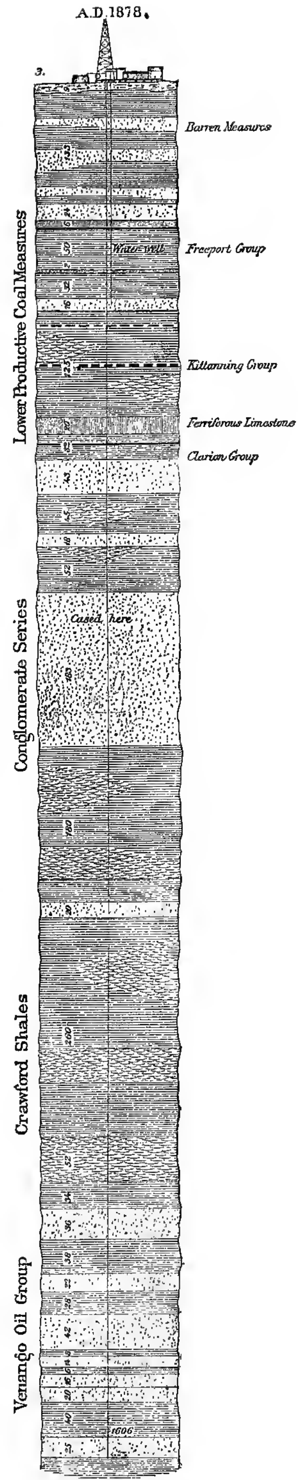
FIG. 91.



Cross section of Well of 1868.

FIG. 92.





Three Oil Well Sections in Pennsylvania, to illustrate the progressive deepening of the borings from 1861 to 1878.

FIG. 93.

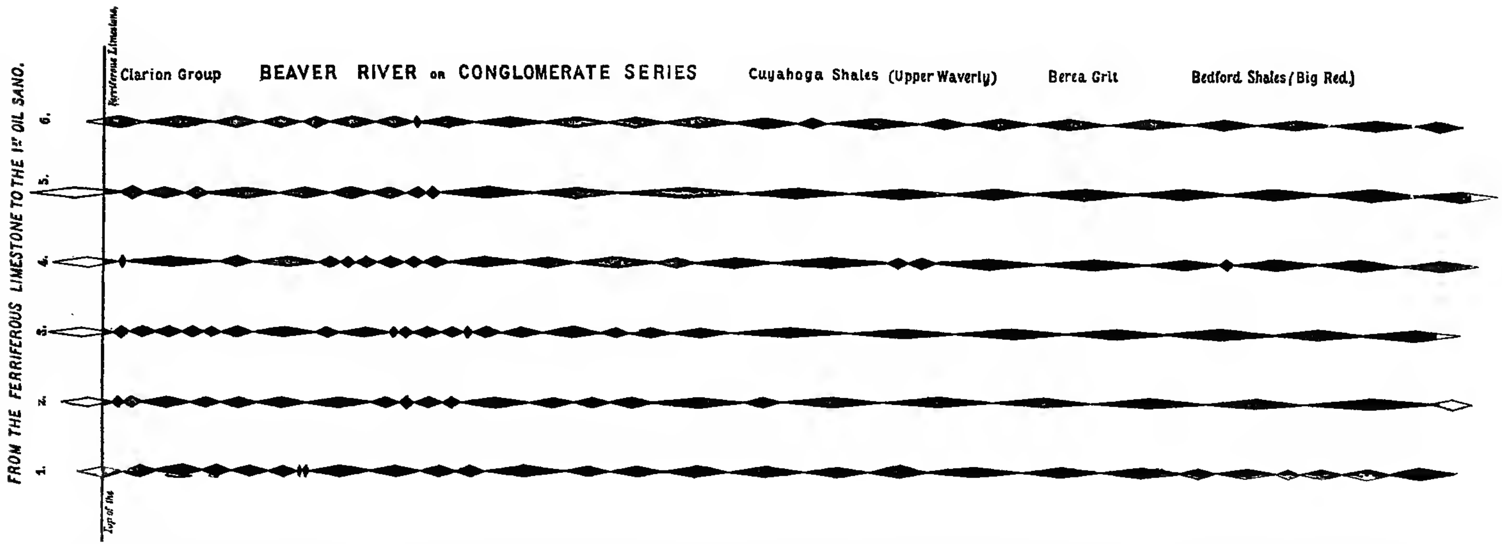


Diagram showing the depth of bore hole completed daily in six wells in the vicinity of Petrolia, Butler Co., U.S.A. Designed to exhibit the variable character of strata drilled through, by the variable results obtained in a given time from a uniform method of drilling. Each diamond represents 24 hours' work, and as the rate of drilling depends upon the quality of the rock, the length of a diamond should indicate whether the rock is hard or soft.

most experienced drillers are able to work successfully at such great depths, and even skilled workmen occasionally fail, for there are wells in the Washington field which have been abandoned with three sets of tools in the hole. The chief difficulty encountered arises from the caving of the rock. The average time occupied in the drilling of a well in this field is four months, and the cost of the well is as much as \$8000, while the cost of wells in the Bradford field does not exceed \$2500 to \$3000. Drilling in the Washington field is paid for at the rate of \$1.75 to \$2.00 per ft.; while in the Bradford field the payment for this work is at the rate of from 45 cents to 60 cents per foot. At this rate of payment, the well-owner provides the derrick (which costs about \$500), the boiler (about 25 h.p., costing about \$500), the engine (about 20 h.p., costing about \$200), and the connections (costing about \$100), while the drilling contractor furnishes the cable, the drilling tools, coal and labour. Occasionally the drilling contractor also provides the engine, boiler and connections, and then receives payment at a higher rate per foot drilled. The contractor pays the driller \$4 per day, and the tool-dresser \$3½ per day, and as there is a night shift and a day shift, the wages amount to \$15 per twenty-four hours. An oil-lease in this field is usually for five years, or as much longer as oil or gas is produced in paying quantities, and the document usually includes a covenant that the lessee is to commence development within one year, or it may be two years, or is to pay a stipulated rent per acre. The landowner or farmer retains the right to use the land for agricultural purposes, the lessee being entitled only to so much of the surface as he may need for the purpose of petroleum production, and for ingress and egress. The terms of such a lease are also usually that the lessor receives a cash payment of \$100 per acre if the district has already produced oil, with one-eighth of the oil produced (in kind).

As an illustration of the sizes and lengths of casing employed in the Washington field, the following particulars, which refer to a well in process of drilling visited by the writer, may be given:—

16 to 18 feet of wooden conductor.

$$\left.\begin{array}{r}\text{682 feet of 10-inch casing}\\ \text{1060 feet of } 7\tfrac{5}{8}\text{-inch casing}\\ \text{1750 feet of } 5\tfrac{5}{8}\text{-inch casing}\end{array}\right\}\text{ internal diameters.}$$

The casing was in lengths of from 17½ feet to 20 feet, carefully screwed together. It will be understood that each string of casing extends from the mouth of the well. Allowance has to be made in drilling for the larger size of the sockets or couplings of the casing, and for the hole not being quite true; accordingly, a 13-inch bit is used for the 10-inch casing, a 10-inch bit for the $7\frac{5}{8}$-inch casing, and a 7½-inch bit for the $5\frac{5}{8}$-inch casing.

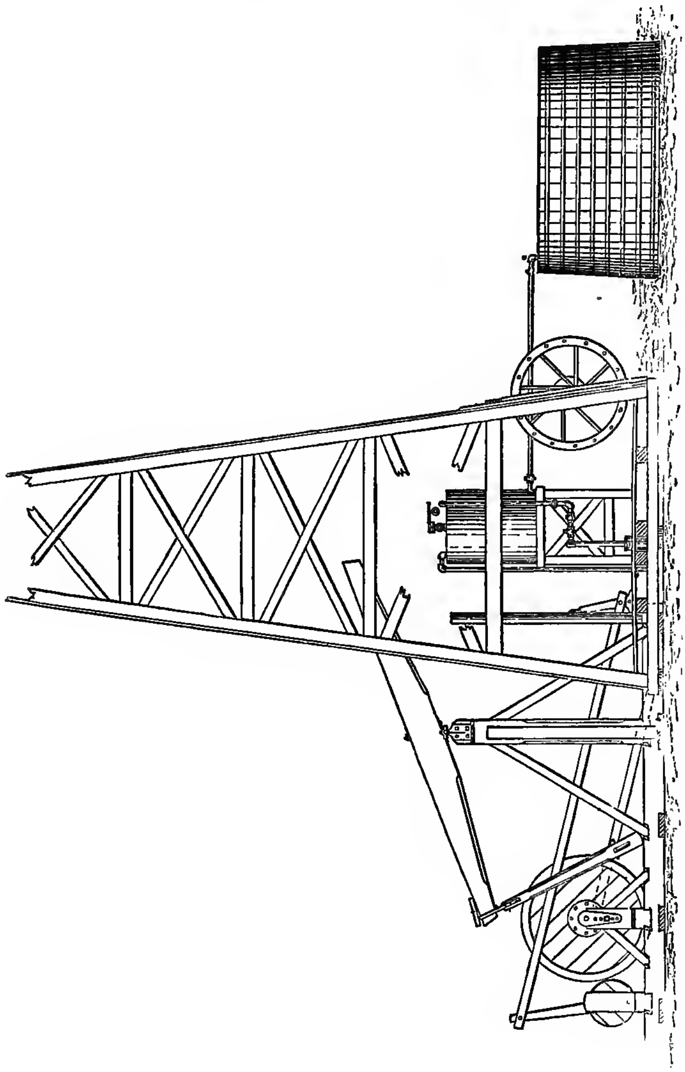
Nearly all the wells in the Washington field were at the time of the writer's visit flowing wells, the flow usually being continuous. The arrangements adopted for the separation of gas and oil obtained from flowing wells are shown in Fig. 94. The maximum regular yield of any one well was probably from 600 to 700 barrels per diem, and in consequence of the great expense of drilling in this field, no well which yielded much less than 100 barrels per day could be considered to pay. It was calculated that one of the wells in this field yielded 3600 barrels every twenty-four hours for about a week after it was completed.*

On the completion of the drilling, the well is "torpedoed," with the object of increasing the flow of oil. The torpedo employed is a charge of nitroglycerine in a suitable *shell*, Fig. 95 (p. 161), which is lowered to the oil-

* The "Armstrong No. 2" well in Butler County, Pa., completed 1884, was estimated to have flowed at the rate of 260,000 imperial gallons per diem (24 hours).

bearing strata and there exploded. The shell is of tin plate, and is usually $3\frac{1}{2}$ inches in diameter by 10 feet in length, a shell of these dimensions holding 20 quarts of the explosive. Formerly there was fitted to the upper end of the shell a "firing-head," consisting of a circular plate of iron, slightly

FIG. 94.



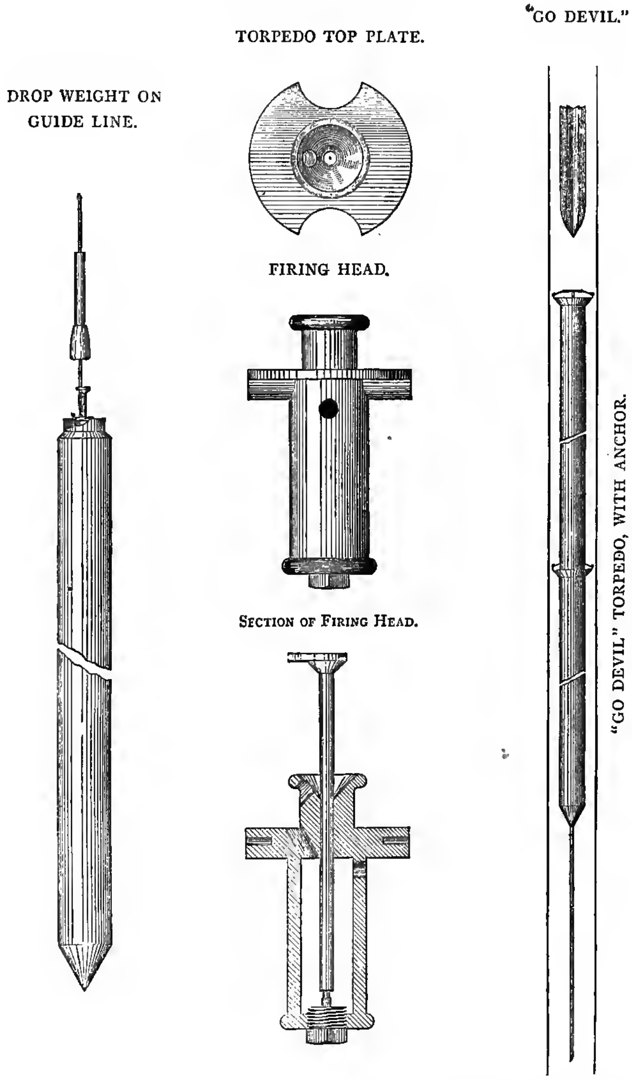
The oil flows into the gas tank (in the centre of the derrick) where it is separated from the gas, and passes into the large tank shown on the right. The gas may be used for fuel or light.

smaller than the bore of the well, attached to the under side of which was a vertical rod or pin, on which a percussion-cap was placed. The cap rested on the bottom of a small iron cylinder, which, like the shell, contained nitroglycerine. The torpedo having been lowered into the well, a heavy cast-iron weight, termed a *go-devil*, was dropped into the well, and this weight, striking the disc, exploded the percussion-cap and fired the torpedo. This method of causing the explosion has been almost entirely superseded

by the employment of what is termed a "go-devil squib." The squib is practically a miniature of the torpedo. Its tin case holds about a quart of nitroglycerine, and it has a firing-head similar to that already described, but without the disc, the percussion-cap being detonated by the impact of a

Fig. 95.

OIL WELL TORPEDOES.



leaden weight running on a cord. The squib is lowered into the well until it hangs suspended by the side of the torpedo; the weight is then allowed to run down the line, the squib is exploded, and this causes the explosion of the large torpedo.

The torpedo is lowered into the well by a cord having at the end a hook

which can be easily disengaged from the wire handle of the shell. The precise position of the torpedo in the well is determined by fixing to the lower end of the shell a tin tube, termed the *anchor*, forming a support of the requisite length. Frequently as large a charge as 80 quarts is employed, four or more shells of the dimensions given, placed one upon another, being used in such cases, and sometimes this quantity is exceeded. A considerable number of firms are engaged in the manufacture of nitroglycerine in the oil-fields, and it has been estimated that in the Bradford field alone more than eight tons of the material were used for torpedoing wells during the month of July 1885. The cans in which the explosive is conveyed to the wells hold from six to eight quarts, and the waggon employed for the transport is commonly fitted with padded compartments for ten cans. The use of the torpedo in wells was patented by Colonel Roberts in 1864, and the operation of torpedoing was subsequently conducted by a company who purchased the patent. The fees charged by the company being high, attempts were made by well-owners and others to prepare their own torpedoes, the persons employed in this secret service being termed "moonlighters." In the Washington field, wells are frequently torpedoed several times, the charges being gradually increased in size. The torpedo is generally exploded under about 50 feet of water. Little or no sound is heard, but a slight quiver of the ground is often perceptible. A few moments after the explosion the fluid in the well is shot into the air with great violence, forming a magnificent fountain, and small pieces of rock are also thrown out. The well may then begin to flow, but there is usually a sufficient interval to admit of the casing being connected with a tank in which the oil is collected. Some authorities are of opinion that the use of the torpedo is of little value, that its effect is simply to clear the pores of the rock of obstruction, and that the apparent increase in the yield of oil is a temporary one, due to reaction from the immense gas pressure produced by the explosion. Many wells, however, that gave little or no oil on the completion of the drilling, have, through the use of the torpedo, been caused to yield abundantly.

The drilling of oil-wells is an operation by no means free from risk. Occasionally, when oil is struck the outrush is so violent that the ponderous drilling tools are projected from the well, and the liberated gas is liable to take fire. Dr. Gesner gives the following description of an accident of this class, which occurred in the early days of the industry :—

"We had gone down 300 feet, and were expecting to strike oil at any moment. We went up to the shanty where we boarded to supper, and on our way back to the well, which was just below in the hollow, we saw the men hurrahing, and presently a jet of gas, water and oil rushed up, fairly lifting the tools out of the well. It roared and hissed like letting off steam from a boiler. The stream seemed to me to mount higher than the derrick, which was 40 feet high. The folks in the neighbourhood ran down with their shovels and dug a circular trench around the well, throwing up a bank to catch the oil, as we had not expected such a flood and had no large tanks ready. The gas mingled with the air, and for a distance about the well the air was almost yellow with the gas and spray of oil from the fountain. Mr. R. and myself looked on a while, and then started to go to the engine-house of the next well to have the fires put out. Before we reached it, however, the gas took fire like a flash of lightning. Mr. R., who was passing a small tank of oil, was covered with it as it took fire also, and I lost sight of him for a moment. My hair and face were burned, but I was not much hurt. The sight of the burning well was terrible. A great fountain of fire, it wavered to and fro as the wind took it, and threw off blazing jets of oil. The poor people who were dipping the oil up in the little pool around the well wilted down like leaves when the forest is on fire.

Some tried to crawl away, but the liquid flame ran along the ground and caught them. Several hundred barrels of oil from a neighbouring well caught fire. Vast clouds of smoke rose from the burning well, and floated off over the hills; and when night set in, the clouds and hills were red with the light of the conflagration. Mr. R. died very soon after. There were a great many lives lost."

In December 1884, a burning well in the Thorn Creek district, estimated to be discharging more than 2500 barrels of oil a day, created a great sensation, the column of flame being 175 feet in height.

The great majority of the wells in the United States oil-fields do not flow, and the oil has to be raised to the surface by a pump. In some cases, however, wells which would not otherwise flow may be caused to do so by the use of the *water-packer*. This device not only prevents water that may pass into the well below the casing from gaining access to the oil-sand, but also stops the ascent of gas through the annular space between the casing and the tubing. There are several forms of water-packer, but the simplest is a ring of india-rubber which is applied to the tubing at the required point, and upon compression is forced against the walls of the well, communication between the outside of the tubing above the packer and the oil-space below it being thus shut off. The pressure of the gas thus confined in the oil-chamber causes the outflow of oil through the tubing. The flow only takes place when sufficient pressure has accumulated, and is generally intermittent. When the well requires to be pumped a valved *working-barrel* with valved *sucker* is attached to the lower end of the tubing, a perforated *anchor* being placed below it. The sucker is furnished with a series of three or four leather cups, which are pressed against the sides of the working-barrel by the weight of the column of oil. Connected with the sucker is a string of *sucker-rods* of the requisite length, the upper end of the top one of the series being attached to the walking beam, Fig. 96. The sucker-rods are screwed together, and are usually of ash, but metallic rods are also used. When a number of contiguous wells, none of which yield largely, are to be pumped, a *grasshopper*, or *sucker-rod movement*, is employed. This apparatus admits of the application, through the medium of simple mechanical contrivances in which old sucker-rods are largely utilised, of the motive power of a single engine to a considerable number of pumps.

The average length of time during which an oil-well in the United States may be expected to yield oil in remunerative quantity, has been estimated at five years, but the period varies within wide limits.

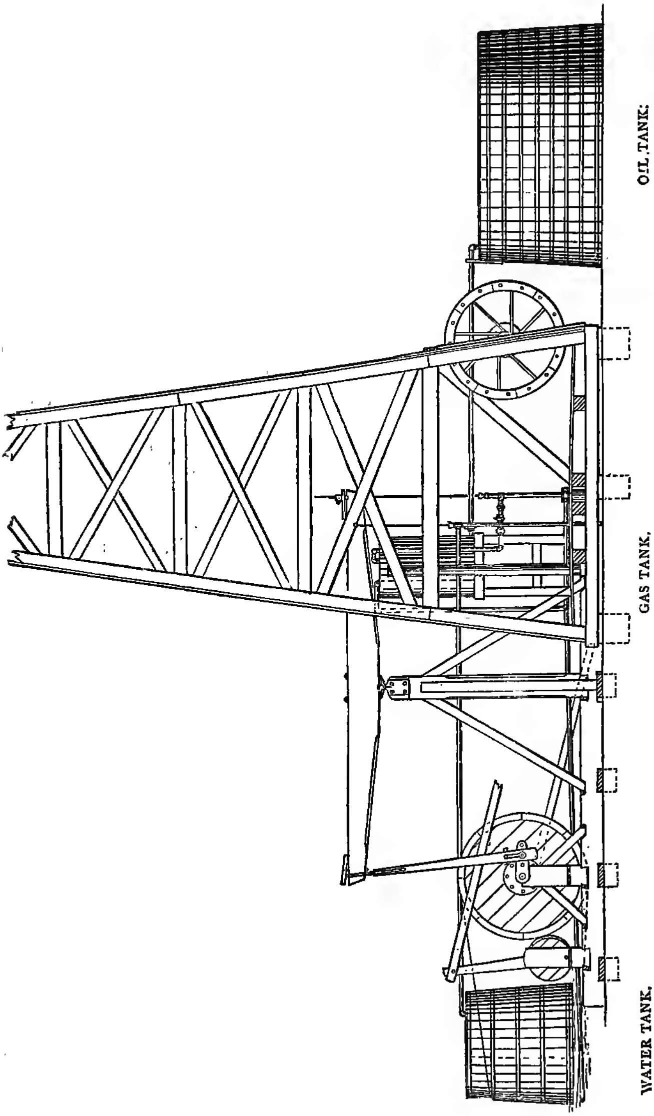
It is usual to remove the casing from exhausted wells for use in new wells. This allows water to pass from the water-bearing strata to the oil-sands, and as it is found that the yield of adjacent wells is prejudicially affected by this "flooding," the Pennsylvanian Legislature has enacted that abandoned wells from which the casing has been drawn are to be "plugged" by filling them with sand.

The practice in the United States is to drill acquired territory as quickly as possible and take out the oil. It has been demonstrated that there is a lateral flow of oil through the oil-bearing strata (in one instance red paint put into a well being pumped out of another about half a mile distant), and it is therefore sometimes impossible for a lessee of oil territory to preserve the oil beneath the surface. The petroleum must be raised, or it would be drained away by wells on neighbouring property.

The wells in Pico Cañon, California, range in depth from 700 ft. to 2000 ft., and are usually commenced with a 10-inch or 12-inch hole, the diameter being reduced as caving occurs. Occasionally the well is completed with a diameter as small as $3\frac{3}{4}$ inches, but efforts are made to carry a $5\frac{5}{8}$-inch

hole down to the principal oil-bearing rock. The length of conductor varies from 10 ft. to 20 ft. Some of the wells have no provision for shutting off water, but all are cased to prevent caving. The length of time occupied in drilling to a depth of 1500 ft. in this locality is from four to five months. The wells are not torpedoed.

FIG. 96.



Both oil and water are pumped, the water-well being a few feet from the oil-well, between it and the Samson post. Both wells have attachments to the walking beam and are pumped by the same stroke. The oil is pumped into the gas tank and there separates by gravitation from the gas, and is then conducted to the oil tank. The gas is led from the upper part of the gas tank to the furnace and is burned under the boiler.

Before the completion of the drilling of the well, a circular wooden tank is erected to receive the oil. Such tanks commonly hold about 250 barrels, but some are of two or even three times that capacity. As soon as the well commences to yield, either by flowing or by being pumped, notice is given to a representative of the transportation and storage company, who connects

the tank, by means of a 2-inch pipe, with the company's mains. When the tank is full the quantity of oil is gauged by the company, 3 per cent. is deducted for "shrinkage," or loss in transportation, one-eighth, or other agreed proportion, is appropriated to the landowner, and the remainder is entered to the credit of the producer in the books of the company. The oil thus received may be compared to a deposit in a bank, and is similarly transferable by written order. Such written order, when accepted by the company, becomes what is known as a "certificate," and is a negotiable document. The oil exchanges only deal in certificates for 1000 barrels, but smaller quantities of oil can be sold. The company allow thirty days free storage, and after that time make a charge per barrel per month as long as the oil remains in their custody. Any oil destroyed by fire is deducted *pro ratâ* from the total stocks, this being practically a system of mutual insurance.

In the early days of the United States petroleum industry, the only method of transporting the oil from the well was to place it in oak barrels holding 40 or 50 gallons, and to convey these barrels by road to Oil Creek, where their contents were emptied into bulk barges holding about 2000 barrels. As Oil Creek was not ordinarily navigable, arrangements were made with mill-owners for the use of the surplus water stored in the dams, and at intervals the barges were floated down from dam to dam until they reached the mouth of the Creek at its junction with the Allegheny river, from which point there was good flat-boat navigation to Pittsburg. This method of transportation was not only very costly, but was also attended with frequent loss of oil through the barges coming into collision while being floated down. On one occasion from 20,000 to 30,000 barrels of oil were thus lost. Added to this, the roads over which the barrels had to be drawn were little better than paths through the woods. Nevertheless, the system, for want of a better, was for some time largely adopted, over 1000 boats, 40 steamers, and 4000 men being engaged in the traffic.

In the latter part of 1862, a branch of the Atlantic and Great Western Railway was carried into the oil regions, and at a later date the Allegheny Valley Railway was opened from Oil City, at the mouth of Oil Creek, to Pittsburg, and a number of narrow-gauge railways were constructed as feeders.

Crude oil was at first conveyed by rail in barrels coated internally with glue, but the small quantity of water present in the oil was found to dissolve the glue and cause the barrels to leak. To remove this difficulty and to reduce the cost of handling the oil, tank waggons were adopted in 1865 or 1866. These waggons at first consisted of an ordinary truck, on which were placed two circular wooden tanks or tubs, holding from 2000 to 4000 gallons. In 1871, a tank car similar to those now employed was introduced. This consists of a horizontal cylindrical tank of boiler-plate, lying upon a truck, and provided with a dome such as a horizontal steam boiler has. The tank is furnished with an orifice in the top of the dome for filling, and with a valve beneath by which it can be emptied. The tank-waggon now employed usually holds nearly 4500 American gallons (3748 imperial gallons), the receptacle being about 24 ft. 6 in. in length by 5 ft. 6 in. in diameter.

Tank barges, 130 ft. in length, by 22 ft. beam, and 16 ft. in depth divided into eight compartments by oil-tight bulkheads, have been largely employed for the conveyance of oil on the Allegheny river.

In 1862, a Bill was introduced into the Pennsylvania Legislature for a pipe-line from Oil Creek to Kitanning; but this, and a subsequent scheme for laying a pipe-line down the Allegheny river to Pittsburg, were strongly opposed and came to nothing. According to Mr. C. L. Wheeler, the credit of having first suggested the laying of a pipe-line belongs to General Karns,

while a Mr. Hutchinson was the first to carry out the idea. Hutchinson's pipe, which was only about three miles in length, was, however, so defectively constructed and leaked to such an extent, that little, if any, of the oil run in at one end reached the other. Professor Peckham states that the first successful pipe was laid by Van Syckle, of Titusville, in 1865. This line (which was four miles in length) and another were afterwards worked by the Allegheny Transportation Company, though not at first without considerable opposition from the teamsters, who more than once maliciously severed the pipes. However, by the employment of armed patrols the lines were preserved from destruction, and after a time the opposition ceased. Gradually, a system of pipe-lines running from the wells to central stations, and thence to loading racks for the filling of tank-cars on the railway lines, was constructed, and in 1867 there were eight or nine companies owning pipe-lines in the oil regions, and issuing negotiable certificates for the oil which they collected.

In the principal oil regions of the United States there is, at the present time, a network of 2-inch piping connecting the various wells with storage tanks, the aggregate length of the piping so employed being several thousand miles.

In 1875, the first trunk line was laid. This extended from the lower oil country to Pittsburg, a distance of sixty miles, and was 4 inches in diameter. Like the first pipe-lines from the wells it had, for a time, to be protected against violence.

As the refining trade developed, it became concentrated on the Atlantic seaboard and on the shore of Lake Erie, and the transportation of the crude material to the refineries became a business of very great importance. From 1878 to 1881–2 the construction of great trunk lines was continuous. Consolidation of the transporting companies also took place, and subsequently the principal pipe-lines passed into the hands of a corporation known as the National Transit Company. This company owns the following trunk lines:

	Length in miles.
From Olean, N.Y. to New York, Bayonne, and Brooklyn	300
From Colegrove, Pa., to Philadelphia	280
From Millway, Pa., to Baltimore	70
From Hilliards, Pa., to Cleveland	100
From Four Mile, Cattaraugus Co., N.Y., to Buffalo	70
From Carbon Centre, Butler Co., Pa., to Pittsburg	60

A total, including duplicate lines, of about 1330 miles. The New York line consists of two 6-inch pipes for the entire distance, with a third 6-inch pipe for a portion of the way, and is provided with eleven pumping stations about 28 miles apart. The transporting capacity of this line is about 28,000 barrels per day. The greatest elevation of the pipe between stations above tide-water is 2490 ft. The Philadelphia line has a diameter of 6 inches, with six stations; the Baltimore line is 5 inches in diameter, without a break; the Cleveland pipe, 5 inches, with four stations; and the Buffalo and Pittsburg pipes, 4 inches, with two stations.

The pipe is made specially, and is of wrought-iron, lap-welded. It is tested to a pressure of 1500 lbs. per square inch, the working pressure being 900 to 1200 lbs., or even more. The pipe is in lengths of 18 ft., provided at each end with coarse and sharp taper threads, nine to the inch, and the lengths are connected with long sleeve couplings, also screwed taper. The line is usually laid two or three feet below the surface of the ground, though in some places it is exposed, and at intervals bends are provided to allow for contraction and expansion. At the different pumping stations there are tanks of light boiler-plate, usually about 90 ft. in diameter, by 30 ft. in

height, the oil being pumped from the tanks of one station to those of the next, though sometimes a loop is laid round a station, and oil has thus been pumped a distance of 110 miles with one engine. The pumping engines employed are the Worthington engines, constructed at the Worthington Works in New York, and at each station there is usually a duplicate set. These engines, which are from 200 to 800 h.p., have independent plungers, with exterior packing, valve-boxes subdivided into small chambers, and leather-lined metallic valves with low lift and large surfaces. The pumps are so constructed that before one plunger has completed its stroke another has taken up the work. The column of oil is thus kept continuously in motion, and the violent concussions which occur when the oil column is allowed to come to rest between the strokes, are avoided. In the older systems of pumping these concussions sometimes resembled the report of a gun, and the pipes were soon rendered defective by the sudden strain.

Besides the tanks at the pumping stations, the National Transit Company own an immense amount of tankage at convenient centres. The tanks now usually employed for storage purposes are 93 ft. in diameter, by 30 ft. in height, have slightly conical wooden roofs covered with sheet-iron, and hold 35,000 barrels each.

The Tide-Water Pipe Company's line consists of a pipe, 6 inches in diameter, extending from Rixford, in the Bradford field (about eight miles as the crow flies, south-east of the town of Bradford), in a general south-easterly direction, to Tamanend, in Schuylkill county, where the oil is transferred to tank-cars and conveyed by the Reading Railroad to Chester, a town fifteen miles from Philadelphia, or to Bayonne, New Jersey. From Rixford to Tamanend is a distance of about 170 miles, and in this distance there are five pumping stations. Instead of the stations being placed, as they are on the National Transit Company's lines, at pretty regular distances of twenty-five or thirty miles apart, they are separated by distances corresponding in some measure with the inclines, the greatest distances being fifty-five miles, and the shortest twenty-four miles. By the use of loop-lines round the stations, the oil is, however, frequently pumped in hot weather, when it is most fluid, a distance of eighty miles. The working pressure is 1000 lbs. per square inch, and the capacity of the line 10,000 barrels per 24 hours. The Holly pump, a three-throw pump with gearing, is used on this line.

The pipe-lines are cleared of obstructions caused by sediment deposited by the oil, by the use of an ingenious instrument, which like the torpedo-exploding weight is termed a "go-devil." This apparatus consists of a conical brush of steel wire furnished at the base, or rear end, with a leather valve in four sections, strengthened with brass plates, and with steel wire guides. The "go-devil" is pumped through with the oil, and travels at the rate of about three miles an hour. Its progress is traced by the scraping sound emitted, and it is followed from one pumping station to another by relays of men. The instrument must never be allowed to get out of hearing, otherwise in the event of its progress being arrested by an obstruction, it may be necessary to take up a considerable length of piping to ascertain its position.

It will be obvious from what has been stated that the identity of the oil run into the pipe-line system is destroyed, and that only a limited amount of classification of the crude oil is possible. The heavy oils from the Franklin and other districts are therefore transported in barrels.

It is by no means uncommon for crude petroleum in the storage tanks to be set on fire by lightning, notwithstanding the general employment of

lightning conductors, the vapour which the oil evolves readily taking fire, and communicating flame to the oil. When a tank has taken fire, the oil is liable to boil over, and to prevent this holes through which the oil may escape are made by firing round shot at the tank from small cannon. Such tank fires are occasionally of great magnitude and involve no small danger to surrounding property. A fire of this nature caused by lightning which occurred in June 1880, continued for three days, and destroyep 200,000 barrels of oil, eight or ten iron tanks, two refineries, two bridges, and twenty or thirty dwellings, the estimated loss being $500,000.

XIV. The Production of Natural Gas in the United States.

The gas-wells in the United States are similar to the oil-wells, but the casing heads are in many instances firmly secured to the ground by chains to prevent their being forced off by the pressure, which sometimes amounts to several hundred pounds per square inch. The gas-mains are also similar to the oil pipe-lines. The first mains laid had a diameter of 6 inches, but piping up to 16 inches diameter is now employed. The diminution of pressure through friction is reckoned at about 5 lbs. per mile for a 6-inch pipe, and 3 lbs. per mile for an 8-inch pipe. According to Mr. Carnegie, the most prolific of the gas-wells yielded about 30,000,000 cubic feet per 24 hours, but half this quantity may be considered as the product of a good gas-well.

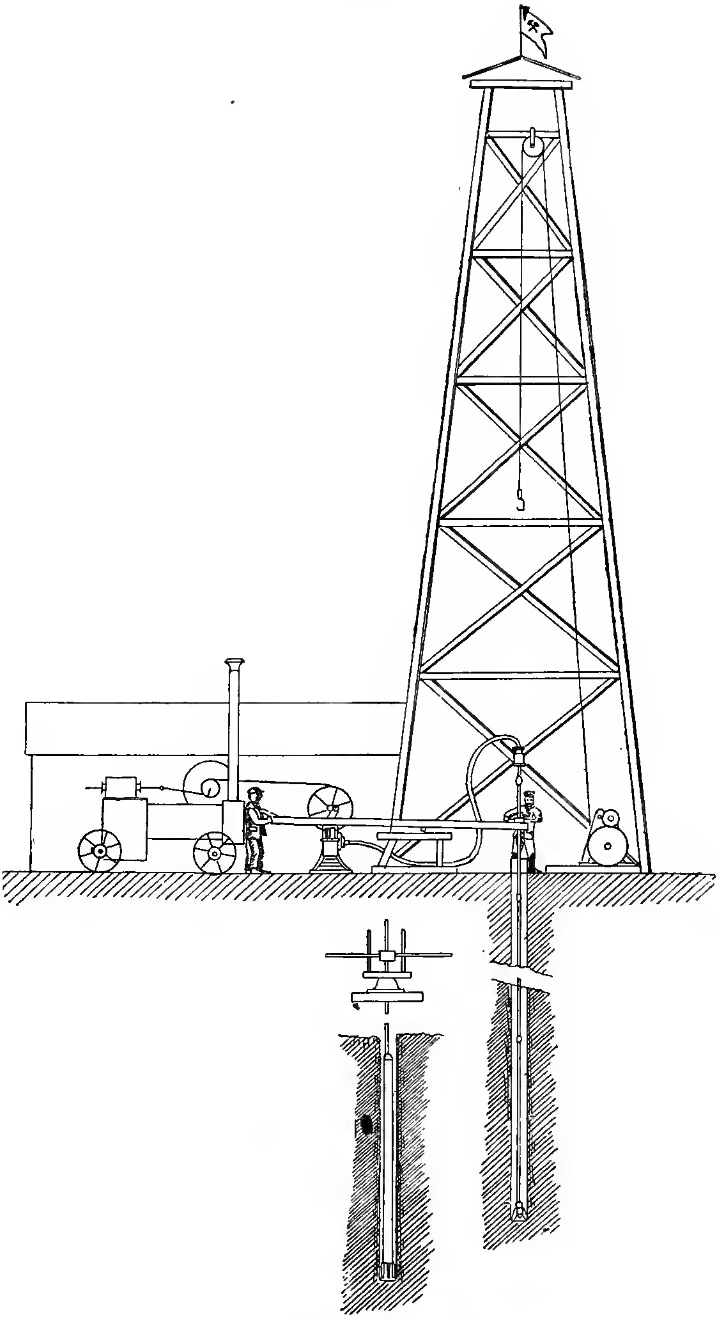
XV. The Production and Transportation of Crude Petroleum in Russia.

In the drilling of petroleum wells in the Baku district and elsewhere in Russia, drilling tools and derricks similar to those already described are employed, but in many cases operators have preferred to substitute for the drilling cable a string of iron rods. These rods are from 40 to 60 feet in length and are screwed together, an additional rod being added from time to time as the drilling proceeds. This system, which had previously been in use in Canada (where, however, wooden rods are employed), is by some considered to be preferable where the strata to be drilled through lie, as in Russia, very irregularly; but it is far less expeditious than the rope system, the loss of time involved in unscrewing the rods, length by length, when the tools are raised for the purpose of dressing the bit or removing the detritus from the well, being very considerable. A few years ago the rod and the rope systems were in use in Russia to about an equal extent, but the rope system is gaining ground. Mr. M. Rydèn (formerly constructing engineer to the Nobel Company) has informed the writer that a wire rope has successfully been employed as a substitute for the manilla cable.

A system of drilling, in which the tools are attached to hollow rods through which a stream of water is forced under a pressure of 50 lbs. per square inch, has been experimentally employed by Messrs. Nobel. Under this system the detritus is continuously washed out of the well by the current of water, and the use of the sand-pump becomes unnecessary. The plant employed in this system (which is sometimes termed the "water-flush" system), with hand labour and steam power respectively, is shown in Figs. 97A and 97B.

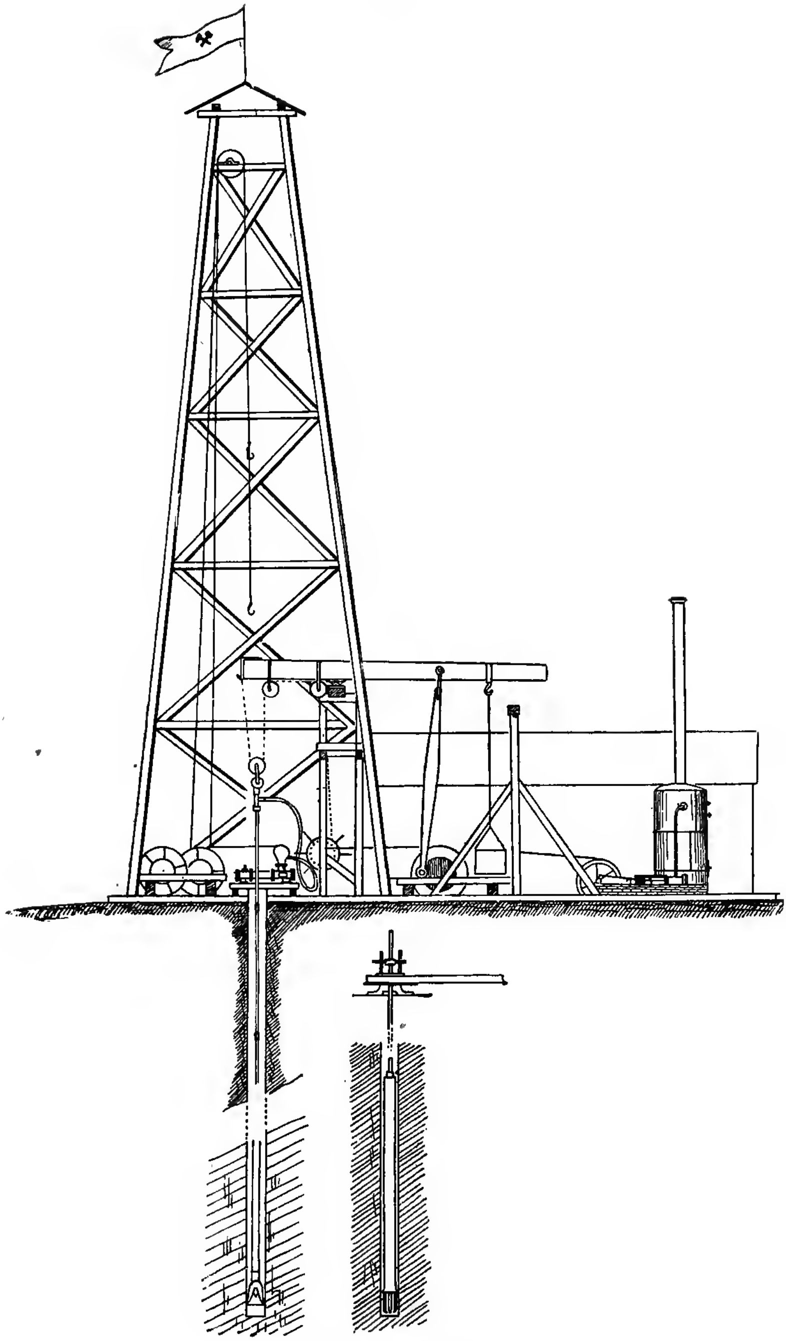
The wells are cased with iron tubing varying in thickness from $\frac{3}{16}$ inch to $\frac{1}{4}$ inch, the casing lengths, when of considerable diameter, being attached by riveting, while those of smaller diameter are screwed together. Vasi-

FIG. 97A.



Water-Flush System.

FIG. 97B.



Water-Flush System.

lieff* estimates the total cost of 16-inch, 14-inch, and 12-inch casing for a well 600 feet deep at £510.

In consequence of the immense pressure exerted by the oil (which sometimes amounts to as much as 300 lbs. per square inch), special provision has to be made for preventing leakage round the outside of the casing. According to Vasilieff, a satisfactory arrangement has been found to consist in first sinking an octagonal well, about six feet in diameter, some 40 feet down to the hard ground, then placing the casing pipe in position, and filling in the space between the pipe and the walls of the well with masonry in cement. The same object has, however, been attained more effectually by tamping the space with puddled clay, rammed in thin layers, after the joint between the pipe and the solid ground has been well caulked with rope-packing. In some cases where the lower strata are in the nature of a quicksand, it has been found practicable to force down the casing with a screw-press.

In the neighbourhood of Baku, it is usual to continue drilling as long as there is a chance of getting a spouting well, and to attain this result it is found necessary to increase the depth of the wells year by year. Thus the average depth of the wells in the Balakhany-Saboontchi field has gradually increased from 420 feet in 1885 to 665 feet in 1889. It has been estimated that the level of the oil is lowered in the Balakhany field to the extent of 56 feet for every 500 million gallons extracted.

The diameters of the 261 wells in the Baku district in 1889 were as follows:

Inches.	No. of Wells.	Inches.	No. of Wells.
6	13	11	5
6½	1	12	39
7	2	12½	6
7¾	2	14	45
8	31	15	2
8½	2	16	15
9⅛	1	18	13
9½	1	20½	1
9¾	1	21	2
10	61	24	1
10¼	15	?	1
10¾	1		

The depths and diameters of the flowing wells in the Baku district in 1889 were as follows:

Depth in (7ft.) Fathoms.	Diameter in Inches.	Depth in (7ft.) Fathoms.	Diameter in Inches.
111[1]	10	112	14
125	6	108	10
121[1]	10	116	14
102	10	118[1]	8
144[1]	10	140	6
122[1]	10	100	8
125[1]	10	124[1]	8
125	10	142	10
114	10	130[1]	6

[1] Continuous fountains, the others flowing intermittently.

Colonel Stewart mentions that the depth of the wells in the Illsk district varies considerably. Thus, well No. 46 of the Standard Russe Company has a depth of 1253 feet, while the neighbouring well, No 43, produces oil from a depth of 680 feet. The diameter of the wells in this district ranges from 20 inches at the surface down to 10 inches at the bottom. In the Kertch field, the depth of the wells is between 800 and 1000 feet, and the diameter from 12 inches down to 6 inches or less.

* "*Gorny Jurnal*" (Russian Mining Journal), September 1885. Translated and abstracted by William Anderson, M.I.C.E., *Proc. Inst. Civil Engineers*, vol. lxxxiii., Sess. 1885 86, Part I.

The length of time occupied in drilling averages from six to eight months. The total cost of a well in the Baku district may be said to range from £1000 to £3000; Mr. Peacock gives the average cost, including labour, derrick, boring tools, casing pipes, boiler, engine, &c., as £2000; whilst Vasilieff estimates the expense of drilling a 16-inch well to 600 feet depth as £1148 12*s*., or with office and other charges, £1300. The average rate of drilling is stated to be 140 feet per month, but about 7 feet can frequently be drilled in a day of ten hours.

Colonel Stewart reports that in the Bibi-Eibat field drilling is paid for at the rate of ten roubles for the first fathom of seven feet, the payment increasing with the depth to ninety roubles for each seven feet at a depth of ninety fathoms. This scale of prices is based upon the furnishing by the owner of the land of all the plant necessary for drilling and casing the well, besides, apparently, upon the understanding that an increased payment is to be made if specially hard strata are encountered.

Mr. Peacock gives the rates of wages as one shilling per day for unskilled labourers, and from two to four shillings per day for skilled workmen. He adds that crown lands on new territories may be leased at the rate of ten roubles per desetine (about 2½ acres). The Standard Russe Company pay a rent to the local Cossack Government of 25,000 roubles for the one and a half million acres of land held by them in the Illski district, and a royalty of two kopeks per pood on all petroleum raised (equal to 1*s*. per 100 gallons).

As soon as the well commences to flow, an iron cap, with a gate valve, is attached to the casing. Messrs. Nobel Brothers' well, No. 32, finished with 8-inch casing in June 1886, required four gate valves to stop the flow, and while the oil was bēing pumped away through three pipes of the respective diameters of 3 inches, 4 inches, and 6 inches, the natural pressure exerted by the oil in the well was so great that the cap was blown away, together with the valves and the strong timbers, the well then discharging mud, stones, and oil for fifteen days, when the flow ceased. It was estimated that the well ejected during this period about 100,000 barrels of oil, and the cessation was attributed to the collapse of the casing at the bottom of the well. The celebrated Droojba well spouted with such violence that for four months the outflow was uncontrollable, all attempts to affix a cap being fruitless. The height of the fountain ranged from 100 to 300 feet, and the surrounding country was deluged with the oil. Moreover, the neighbouring engine-houses and workshops were partially buried in the sand ejected with the oil, and many claims were made for the damage thus done. The estimates of the quantity of oil lost ranged from 68,000,000 to 136,000,000 gallons. Mr. Marvin states that the Droojba well spouted for 115 days before it was capped, yielding 3400 tons a day for 43 days, 1600 tons a day for 31 days, 900 tons a day for 30 days, and 600 tons a day for 11 days. The Markoff well, not far from the Droojba, spouted in 1887 oil and sand to a height of 400 feet, and on a windy day the oil spray was carried to a distance of eight miles. In the previous year, a well drilled by Tagieff ejected for a time 11,000 tons a day. According to Mr. Chambers, the Mining Company's well, completed in August 1887, at a depth of 790 feet, flowed the full size of the casing (12 inches), to a height of 200 feet above the derrick, for 69 days. The lowest estimate of the production for the 69 days was 3,000,000 barrels, and of this about one-third was lost, the capacity of the available tanks being insufficient. So much sand was thrown up with the oil that some buildings about 15 feet in height within 100 yards of the well were buried out of sight, and over an area of probably ten acres round the well the ground was covered with sand to a depth of from one to fifteen feet. The production of this well, after 69 days, declined to 200 or 300 barrels a day, and the efforts to increase it were unsuccessful. When visiting Baku in 1884, the

writer saw one of Nobel's capped wells flowing. As soon as the valve was opened, the stream of oil rose to a height of about 100 feet, and this mighty fountain continued to play with a loud roaring sound, forming a small lake of oil in the neighbourhood of the derrick, until the valve was again closed.

Vasilieff puts the average yield of the wells in active work in 1885 at 32 tons per well per day. Owing to the low price of crude oil which has prevailed (two kopeks per pood, or about *2s. 6d.* per ton delivered at the refinery) it has been customary to keep the flowing wells in reserve, for there does not appear to be in the Baku district the same necessity that there is Pennsylvania to raise the oil to the surface in order to prevent neighbouring wells from taking it.

When the wells do not spout, the oil is raised in cylinders resembling the sand-pump already described, the presence of sand in the oil, sometimes to the extent of 30 or even 40 per cent., rendering it impossible to use a pump such as is employed in the United States. The cylinder holds commonly about 45 gallons, and it is stated that with one such appliance from 18,000 to 20,000 gallons can be raised in a working day of ten hours.

As far as the writer is aware, the torpedo is never used in the Russian wells.

The ordinary duration of production of the wells appears to range from two to nine years. The Kormilitza, or "Wet-nurse" well, gave for twelve years 32,000 gallons a day, while Meeizoeff's No. 5 well yielded 40,000 gallons a day for six years.

The crude oil, having been allowed to deposit the sand and water held in suspension, is conveyed to the Baku refineries principally through pipe-lines, though a certain quantity is carried by rail in tank-cars. Up to 1875, the oil was transported in casks by cart, as much as £100,000 per annum being paid for the carriage. The first pipe-line was constructed by Messrs. Nobel Brothers, and there are now no less than twenty-two lines from the wells to the refineries, eight or nine miles distant. The internal diameter of some of the lines is as much as 8 inches.

XVI. The Production, Transportation, and Storage of Crude Petroleum in Canada.

In the Canadian oil-fields, the drilling contractor usually employs his own derrick, engine, boiler and tools, furnishes wood and water, cases the well and fixes the pump; the well-owner providing the casing and pump, and subsequently erecting the permanent derrick. The wells in the Oil Springs field were formerly from 200 to 300 feet deep, but the petroliferous formation at this depth became water-logged, and the wells, which were subsequently sunk to a depth of about 375 feet, were cased to a depth of about 275 feet to shut off the water. The contract price for drilling a $4\frac{5}{8}$-inch hole to a depth of about 375 feet under the conditions mentioned, was $150, and the time occupied in the drilling was usually about a week, the work being continued day and night. In the Petrolia field, the wells have a depth of about 480 feet, the contract price, including the cost of 100 feet of wooden conductor, being $175, and the time required for the execution of the work being from six to twelve days. The drilling is done with pole tools, the poles being of white ash and 37 feet in length.* The derrick is about 48 feet in height. An auger some four feet in length and about a foot in diameter, is used to bore through the earth to the bed rock, the rotating of the auger being effected by horse-power. The drilling tools

* A full description of the improved Canadian rig and drilling tools employed in Galicia will be found in the next sub-section (p. 175 *et seq.*).

commonly consist of a bit, two and a half feet in length by four and five-eighths of an inch in diameter, weighing about 60 lbs., a sinker-bar, into which the bit is screwed, 30 feet in length by three inches in diameter, weighing about 1040 lbs., and the jars, inserted between the sinker-bar and the poles, about six feet in length and weighing 150 lbs. The tools are suspended by a chain which passes three times round the "spring-pole" at the end of the walking-beam, and thence to a windlass with ratchet-wheel, termed the "slipper-out," fixed on the walking-beam. The object of the "spring-pole," which may be regarded as a supplementary part of the walking-beam, is, as its name indicates, to provide a certain amount of elasticity, and the "slipper-out" furnishes the means of gradually lowering the tools as the drilling progresses. The cable is thus only employed in raising the tools from the well and lowering them into it. The sand-pump is frequently as much as 37 feet in length and is about four inches in diameter. The wells are torpedoed on completion with from eight to ten quarts of nitroglycerine, at a cost of a dollar per quart. The casing ($4\frac{5}{8}$ inches diameter) costs about 45 cents per foot, and the $1\frac{1}{4}$-inch pump with piping costs from $65 to $85, according to the length of pipe required. An ordinary square frame derrick costs with mud-sill from $22 to $27, and the walking-beam about $8. A three-pole derrick, which is commonly used when the drilling derrick, which is portable, has been removed, can be erected at an expense of $10. A 100-barrel wooden tank costs, erected, $50.

The maximum yield per well is ten barrels per day, and the minimum yield for which it is considered profitable to pump is a quarter of a barrel. The yield being in some cases so small, it is usual to pump a number of wells through the agency of one engine, the various pumps being connected with the motor by means of wooden rods. In one instance, the writer saw no less than 80 wells being thus pumped from one centre. The motive power was a 70 h.p. engine which communicated motion, similar to that of the balance-wheel of a watch, to a large horizontal wheel. From this wheel, six main rod-lines radiated. The length of stroke of the main lines was 16 inches, and the rate of movement 32 strokes per minute. Some of the wells being pumped from this centre, were from one-half to three-quarters of a mile distant, and altogether about eight miles of rods were employed in the pumping of the 80 wells.

The pipe-line system in Canada has not been fully developed, and accordingly, in many instances, the well-owner has to convey his oil by road to the nearest receiving station. For the conveyance of the oil by road, a long and slightly conical wooden tank or barrel, resting horizontally on a waggon, is employed. These vessels hold from eight to ten barrels of oil. The Petrolia Crude Oil and Tanking Company is the principal transporting and storing company. The storage charge is one cent per barrel per month, and the delivery charge two cents per barrel.

The storage takes place for the most part in large underground tanks excavated in the clay. These remarkable tanks are often as much as 30 feet in diameter by 60 feet in depth, and hold from 5000 to 8000 barrels. In the construction of these tanks, the alluvial soil, of which there are about 18 or 20 feet above the clay, is curbed with wood and well puddled with clay. On the completion of the excavation the whole walls from bottom to top are then lined with wood (rough pine rings) so that the upper part down to the solid clay is doubly lined. The bottom is not treated in any way. The roof of the tank is of wood, covered with clay. The cost of such a tank is about 22 cents per barrel ($1760 for an 8000-barrel tank), and the time occupied in making it is about six weeks.

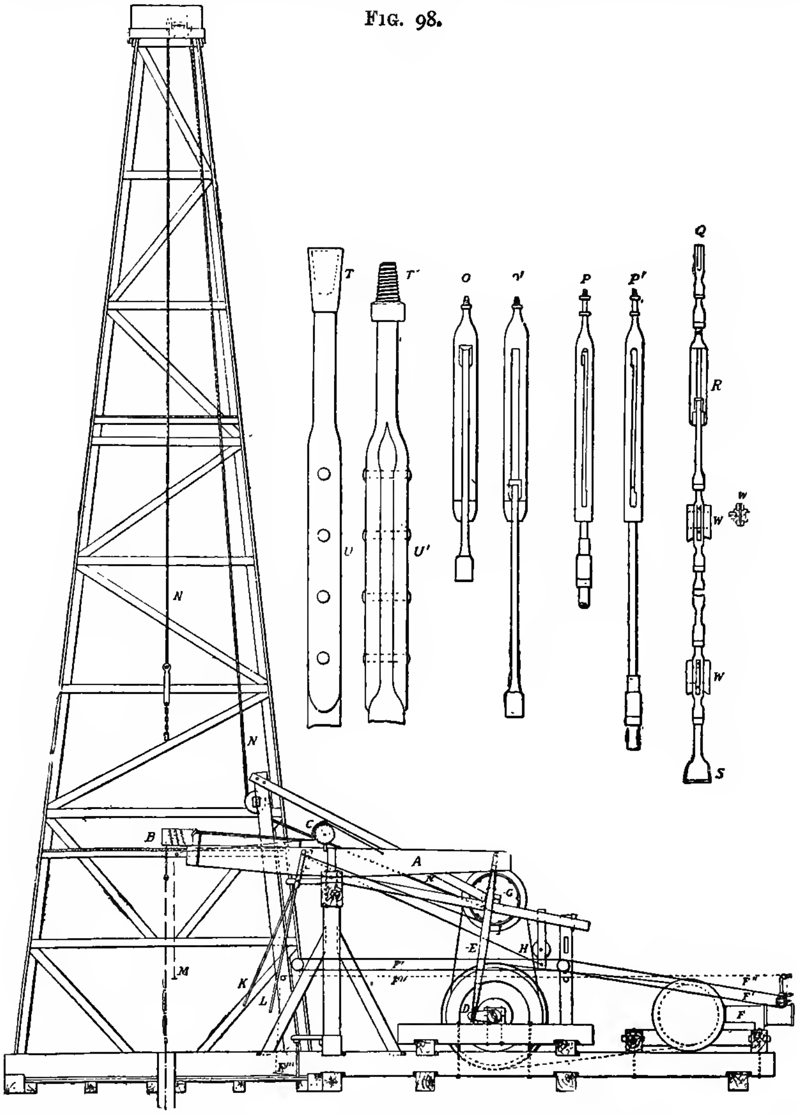
XVII.—The Production of Crude Petroleum and Ozokerite in Galicia.

In the first instance, the drilling of petroleum wells in Galicia was effected by means of the hand-rig described in Sub-section XII. (see Fig. 76, p. 138), but about the year 1867 the substitution of steam power for manual labour was commenced, the use of the "free-fall" jars being retained. The driller was thus enabled to use far heavier tools, the weight of the falling portion ranging from 800 to 1000 kilogrammes, and the work was rendered more expeditious, the writer having seen as many as forty blows of the bit delivered each minute. The free-fall jars are shown in Fig. 98 (p. 176), *P P'*. Whilst, however, the substitution of steam power for manual labour in drilling with free-fall jars was an important step in the progress of the industry, a still more important advance was made when the Canadian system was introduced in 1882; but even that system was found to require modification in certain details in order to adapt it to the special circumstances of the case, the character and disposition of the strata rendering drilling far more difficult as a rule in Galicia than it is in Canada. The derrick and "transmission," as well as the principal tools, employed in the Galician modification of the Canadian system are shown in Fig. 98. The derrick is 17.7 metres in height, 5 metres square at the base, and 1 metre square at the summit. It is boarded on the outside. The working beam, *A*, is of timber. The end of this beam which is over the well, is cased with a spirally grooved cylinder of iron, *B*, carrying the chain supporting the drilling tools. The chain is coiled several times round the cylinder, and then passes to the "slipper-out," *C*, a small winch, with ratchet, fixed on the beam. The working beam is caused to oscillate, so that each end has a vertical movement of about a foot, by means of the crank, *D*, and the connecting rod, *E*. The motive power is a horizontal high-pressure engine, *F*, of about 15 h.p., specially designed for the work. Steam is supplied from a boiler of the locomotive type. It will be seen from the illustration, Fig. 98, that the driller in the derrick can start, stop or reverse the engine, having control of the throttle-valve in the steam-pipe, through the medium of the "telegraph" or endless cord, *F'*, and of the reversing link, by means of the cord, *F'''*, attached to the foot-lever, *F''*. The engine also, by means of a belt, drives the windlass, *G*, for drawing up the tools. This belt runs loose when drilling is in progress, and is tightened by the application of a roller, *H*. A smaller windlass or winch for use with the sand-pump is sometimes employed, and is similarly driven. The larger windlass is provided with a brake, *I*, which is applied when the tools are being lowered into the well. The slipper-out, the roller for tightening the belt, and the brake are also all under the control of the driller in the derrick, the roller and brake being respectively applied by means of the levers *K* and *L*, and the ratchet of the slipper-out being released by pulling the chain, *M*. A manilla hemp cable, *N*, is usually employed in raising the tools, but in many cases recently a wire rope has been adopted, and is found to be far more durable.

The jars, *O O'*, as will be seen, differ essentially from the free-fall jars, *P P'*. There is no arrangement for locking them when telescoped, and indeed the functions of the two arrangements are quite dissimilar. In drilling with the Canadian jars, the whole string of tools, *Q*, with the rods to which they are attached, descends, the blow being then struck, and the jars, *R*, partially closing; as the rods rise, the jars at once fully open before the bit, *S*, is lifted, and the impact of the two links of the jars on this upward stroke is of service in dislodging the bit if it has become wedged in the rock. As the drilling progresses, the driller slightly turns the tools, so

that the chisel-shaped bit, *S*, is caused to make a round hole. The tools are attached to the beam, or rather to the short chain already mentioned, by means of rods. These are of wood (ash), 2 inches in diameter and 16 feet in length. They are connected by means of conical screw joints, *T T′*, attached to the rods by iron straps, *U U′*. The guide, *W*, is an important

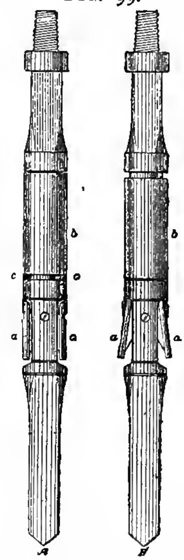
FIG. 98.



adjunct to the ordinary Canadian tools, which has been found necessary in Galicia, in order to preserve the vertical course of the well. It consists, as will be seen, of four wings, radiating from a common centre, and is inserted in the string of tools above the bit. During the progress of the drilling, the well is "cased," or lined with iron tubing. A portion of this casing serves to exclude water from the well, but below the water-bearing rocks the casing is necessary to hold up the rock and prevent "caving." The difficulties met

with in drilling in Galicia are chiefly due to the dislocated character of the strata, and the alternations of hard and soft beds. In some places the strata are disposed nearly vertically, and it will readily be understood that in drilling through soft and friable rock into hard rock at such an angle, the tools are very liable to be deflected, and caving is also very likely to take place. The guides are of great value in keeping the hole straight, and caving has to be prevented by following the bit closely with the casing. Where the drilling is, in consequence of caving, exceptionally difficult, "under-reaming" has to be resorted to. This consists in the use of an *expanding reamer*, Fig. 99, by means of which the well may be drilled of a size slightly greater than the external diameter of the casing. The instrument is provided with a pair of pivoted wings, or dogs, *a a*, which are forced outwards into the position shown in *B*, by the pressure of a powerful helical spring (enclosed in the tubular rod), exerted through the medium of the sliding collar, *b*. When the under-reamer is to be inserted in the casing, the sliding collar is raised, as shown in *A*, and retained in that position by small wedges, *c c*. The wings, or dogs, then lie flat against the rod, as shown in *A*. A few strokes of the tools dislodge the wedges, the dogs at once spring out into the positions shown in *B*, and the well is "reamed" to a diameter admitting of the descent of the casing.

Fig. 99.



Expanding Reamer.

The Canadian system of drilling has almost entirely superseded the free-fall system in Galicia. It is undeniably more rapid, and, as it is carried out with far less concussion, the risk of caving is reduced. The rate at which the blows of the chisel are delivered with Canadian tools varies with the character of the ground; sometimes as many as 70 strokes a minute may be given, but the number usually ranges between 40 and 60.

It is usual to case the upper part of the well with what is known as riveted casing. This consists of tubing made of sheet-iron, with riveted seams, and is not water-tight. To shut off the water, artesian casing, consisting of wrought-iron lap-welded tubing, with screwed joints, is employed. The casing is added in successive lengths during the drilling of the well, until it cannot be forced down any lower. The diameter of the well is then reduced, and a smaller casing used. In this way, a completed well may have several "strings" of casing in it, each reaching to the surface. It is, however, a common practice to remove some of the artesian casing on the completion of the well, taking care to leave that which shuts off the water, but the riveted casing is not withdrawn. In many instances it is found advantageous to use perforated casing below the horizon of the water-bearing rocks, as this, while preventing caving, allows oil to percolate into the well. Some wells are completed with riveted casing of small diameter, extending from the bottom of the bore-hole to the lower end of the string of smallest sized artesian casing. The following particulars of the casing of a well, inspected by the writer, may make the foregoing description clearer:

A. 33 feet of 13 inches riveted.
B. 65½ feet of 11 inches artesian.
C. 124½ feet of 8½ inches artesian.
D. 213 feet of 6½ inches artesian.
E. 433 feet of 4⅝ inches artesian.
F. 236 feet of 4 inches artesian, perforated.
G. 75½ feet of 3½ inches riveted, perforated.

The water was shut off with the $8\frac{1}{2}$-inch casing, and the $6\frac{1}{2}$-inch was withdrawn on the completion of the well. Of the foregoing strings of casing, A, B, C, D and E extended to the top of the well, while F lined the well from the bottom of E for 236 feet, and G completed the lining from the bottom of F for the remaining $75\frac{1}{2}$ feet

The rate of drilling in the Ustrzyki district commonly ranges from 12 to 18 up to as much as 50 or 60 feet in twelve hours, according to the hardness of the strata. Not infrequently considerable delay is caused by the breakage of the tools or rods, and some of the resulting "fishing" operations demand much skill and patience.

The following is the approximate cost in Central Galicia of an outfit for drilling by the Canadian system:

Derrick and transmission	£90
Engine and boiler, 15 h.p.	250
Drilling and other tools and pump	410
Poles and belting	200 to 250
Casing	300 to 500
	£1500

The drilling is frequently done by contract at 8*s*. a foot, the contractor finding labour inside the derrick (a wrench man, a scaffold man, and a third man for odd jobs), while the well-owner provides a smith, a machinist, and a helper, in addition to fuel for the boiler and oil for lubrication and lighting. Labour is cheap, and the natives have exhibited considerable aptitude in acquiring the art of drilling; but owing to the number of church holidays it is desirable to adopt labour-saving mechanical appliances as far as possible. In most parts of the oil-fields, fuel and water are abundant.

The Canadian system of drilling with poles has hitherto been found well suited for use in Galicia, and those who are accustomed to employ it contend that without poles it would be very difficult, if not impossible, to drill in some localities in that country. A serious loss of time is, however, necessarily involved in disconnecting and re-connecting the poles each time that the tools have to be drawn up when any great depth has been reached, and if an oil-bearing formation lying considerably lower should be found in Galicia, attempts will doubtless be made to substitute the cable for the poles.

The diamond-boring system has been tried in Galicia, but does not appear to have given good results. The writer saw an uncompleted well in the Sloboda-Rungurska district which had been in process of drilling for over a year, and had only reached a depth of 220 metres. In a paper read before the Civil and Mechanical Engineers' Society in 1889, Mr. R. Nelson Boyd gave some details of the drilling of a well at Polana by the Aqueous Diamond-Boring Company. The power was supplied by a 12 h.p. engine, and the crown was driven at the rate of 120 revolutions a minute. The quantity of water forced into the hole under a pressure of $1\frac{1}{3}$ atmosphere was 1.52 cubic metre an hour. This was, however, in excess of the necessary quantity, and about one-third of a cubic metre an hour was lost. About 75 per cent. of the water requisite may be saved, so that the actual consumption would be about half a cubic metre an hour. At a depth of 200 metres the drawing of the rods, the removal of the core, and the lowering of the crown again, occupied two hours, and this had to be done for every ten feet of boring. In shale, as much as 2.7 metres were bored in an hour, and in sandstone 0.828 metre. Mr. Boyd considers that the results obtained in this well were of a favourable character, but he points out that the inclination of the strata constitutes a great impediment to the use of

the diamond drill in Galicia, as the upper part of the stratum perforated is liable to slide on a joint and jam the core.

The depth of the wells in the Ustrzyki district is usually from 220 to 250 metres, the first indications of oil being met with at a depth of 30 metres, the first oil horizon being perforated at 120 metres (the well then yielding from three-quarters of a barrel to one barrel a day), and the second oil horizon at 160 to 220 metres. It is believed that a third and probably more productive oil horizon may exist at a greater depth in this district, but the wells are not drilled below the second, when they usually yield about 20 barrels of oil per diem, but sometimes much more. In the Sloboda-Rungurska district the depth of the wells commonly ranges from 215 to 330 metres, but in some instances exceeds 400 metres. The writer was informed that the average time occupied in the drilling of a well in this district is three months, but he saw a well there, stated to be flowing at the rate of 70 to 80 barrels a day, which was drilled to a depth of 220 metres, with a diameter of 6 inches at the bottom, in 18 days. About 25 per cent. of the wells drilled in this district have been unproductive, and the yield of the remainder appears to have varied considerably. Many of the wells flow at first, and afterwards need pumping. One produced for a time as much as 300 barrels per diem, and afterwards for a year an average of 200 barrels a day. The smallest yield for which it is considered profitable to pump in this district is two barrels a day. In the Wietzno field, the writer saw a well out of which oil was flowing simultaneously from two horizons through the 5-inch and 6-inch casings respectively. The estimated yield of this well was 200 barrels a day. The depth of the wells in this field is about 250 metres. In the historic Bobrka field, there were at the time of the writer's visit some 30 wells being pumped, some of which had yielded small quantities of oil for 17 or 18 years, but the ordinary life of a drilled well in Galicia is perhaps one-third of this period. The usual experience has been that, provided a distance of 20 metres intervenes, one well does not drain another. The deepest drilled well in the Bobrka field at the time of the writer's visit had a depth of 409 metres, and a diameter of 6 inches at the bottom.

The pumps used in raising oil from those wells which do not flow are of small diameter (1 to $1\frac{1}{2}$ inch) and are furnished with double or triple buckets with ball valves. The working barrel is placed at the bottom of the well, and $\frac{1}{2}$-inch gas-piping is frequently used as a sucker-rod. To economise steam power a number of pumps are worked from one engine through the medium of rods, the power being thus sometimes transmitted to a considerable distance.

The oil is conveyed to the refineries partly in barrels by road, and partly in tank-waggons by rail. In some cases short pipe-lines have been laid down from the wells to the railway to facilitate transportation. The railway rates for transport are moderate and the companies possess tank-waggons.

The drilling leases in Galicia are commonly for a period of 25 years, the lessee making a cash payment for the lease, the amount depending upon the character of the territory; for this he obtains the usual rights of ingress and egress, the agricultural rights remaining with the lessor. The royalty payable by the lessee ranges from $12\frac{1}{2}$ per cent. to as much as $37\frac{1}{2}$ per cent. of the oil raised, and the lessee also pays a small rent for the land actually occupied by him. The system of land registration admits of drilling rights over oil-lands being intabulated in the land-books, and thus affords to the petroleum producer perfect security at a trifling cost.

In mining ozokerite, it is usual to sink a circular well 3 metres in diameter through the upper beds of clay until the water level in the gravel is reached. This well may have a depth of 14 to 16 metres. In the centre of it, a shaft 1.3 metre square is built up of balks of timber jointed together, the inter-

vening space being filled with clay. The digging and timbering of a shaft 1.3 metre square is then continued until further progress is arrested by water or inflammable gas. When this occurs, one of the veins of ozokerite intersected by the shaft is opened up and followed by means of a timbered gallery. Immense pressure is exerted by the semi-fluid ozokerite, and it is usual to employ timbers nearly a third of a metre square placed about one metre apart. The horizontal galleries cannot without risk of accident be driven further than about 5 metres. The sinking of the circular well costs about 4 fl. the metre, but in the dislocated beds below, where the ozokerite is met with, the cost of sinking is from 5 fl. to 10 fl. the metre run, without reckoning the cost of pumping out the water. The driving of the galleries is paid for at the rate of 7.50 fl. to 9 fl. per metre run.

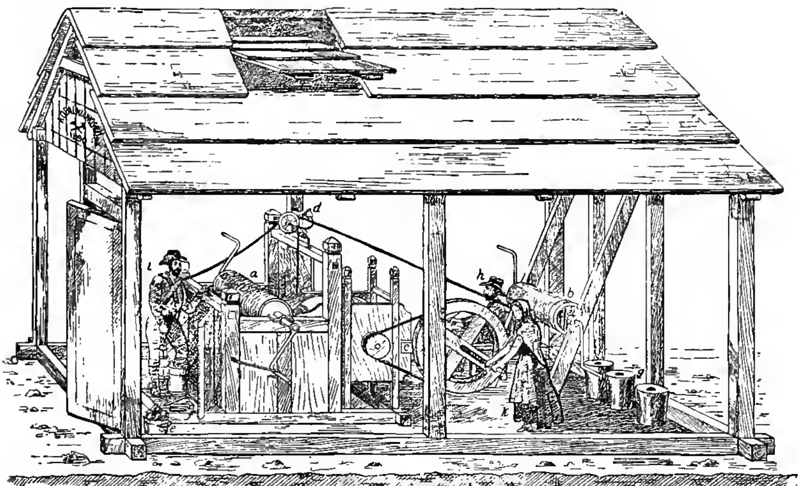
Over the mouth of the shaft is fixed a windlass carrying a wire rope, to each end of which is attached a bucket used in drawing up the ozokerite, or in lowering and raising the miners. The descent is made by placing one foot in the bucket and holding on to the rope, the other foot being used in fending the bucket off the sides of the shaft. The miner wears a safety-belt, to which is attached a rope passing over a smaller windlass. As inflammable gas is met with in the workings, safety-lamps are used; and air is forced into the galleries by a fan-blower, which is usually worked by a woman. Within easy reach of the miner is a cord communicating with a bell at the mouth of the shaft by means of which he can summon assistance; but notwithstanding the provision of the bell and the safety-belt, deaths from suffocation are not uncommon. The underground miners receive 0.75 fl. to 1.25 fl. per day, while the labourers employed above ground get about 0.60 fl. It is stated that of the 10,000 work-people engaged in the industry in 1871, 2000 were underground miners, and that among these there were usually from 200 to 300 accidents per annum, most of which were fatal. According to another authority, the "admitted" annual death-rate due to accidents ranges from 7 to 15 per thousand (the rate in "ordinary mining" being given for comparison as 1.88 per thousand), but it was considered that the number of casualties was understated. There seems to be good reason to believe that notwithstanding the existence of a staff of officials specially charged with the duty of enforcing a code of regulations, much of the underground work is carried on under unnecessarily dangerous conditions. The primitive manner in which ozokerite is mined is clearly shown in the illustrations, Figs. 100, 101, which are taken from a model made in Galicia and presented to the writer.

Distributed over an area of 90 to 100 hectares are many thousand shafts ranging in depth from 20 to 200 metres, but the writer was informed that not more than 400 of these were being worked at the time of his visit to Boryslaw. The shafts are in many cases not more than from 3 to 8 metres apart, and the available ground round each shaft usually ranges from 9 to 60 square metres. When it is considered that there are hundreds of separate proprietors, it will be understood that there is frequently considerable confusion and great difficulty in getting rid of the earth excavated and raised with the ozokerite. Recently, however, arrangements have been made for the systematic removal of the débris.

Attempts have been made to place the industry upon a more satisfactory basis, and a French company has carried out the system of mining the ozokerite by means of a main shaft, fitted with cages running in guides, and operated by a steam-engine, as in coal-mining, the galleries being ventilated by steam-driven centrifugal exhausters. The locality selected for the shaft being, however, near Wolanka, which may be regarded as outside the zone of the most productive territory, the system cannot be said to have had a fair trial.

The ozokerite occurs sometimes in sheets as thin as paper, but more often in veins from 2 or 3 inches to a foot in thickness, disposed in the most

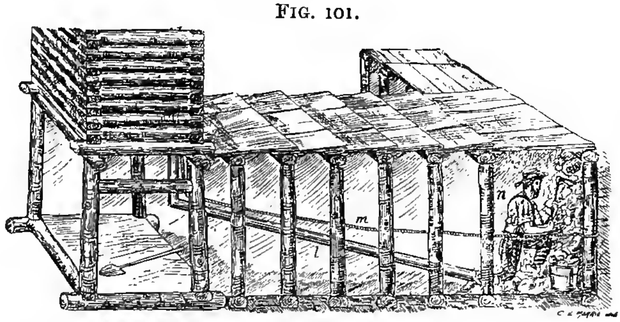
FIG. 100.



Shed in which the above-ground work is carried on. In practice the sides are boarded up, and a ventilator for the escape of the gas from the mine is provided in the roof, as shown.

a. Windlass for lowering and raising miners, and raising ozokerite.
b. Windlass carrying rope attached to miner's safety-belt.
c. Rotary blower for ventilation.
d. Signal bell.
e. Bucket in which the ozokerite is raised.
f. Hammer, chisel, and pick used in the work of mining.
g. Blocks of cast ozokerite.
h Proprietor of the mine keeping an account of the ozokerite raised.
i. Miner, wearing safety-belt, and carrying safety-lamp, preparing to descend.
k. Woman working blowing machine.

FIG. 101.



View of portion of shaft and gallery, showing mode of timbering.

l. Tube conveying air from blowing machine.
m. Signal cord.
n. Miner at work.

irregular manner. The mineral is broken out by hand with the pick and wedge, and this may be regarded as easy work owing to the disturbed character of the strata in which it occurs. The water and oil with which

the ozokerite is associated are pumped up from the bottom of the shaft. For the working of each shaft two miners, two labourers, and one woman are needed.

The Boryslaw ozokerite deposit extends over a pear-shaped area, the outer zone of which has a length of 1500 metres and a breadth of 560 metres, the dimensions of the inner zone being 1000 metres by 350 metres. The deposit narrows considerably as the depth increases.

An attempt has been made to estimate the quantity of ozokerite in this deposit. The basis of the calculation is that the territory constituting the outer zone contains 2 per cent. of the mineral, whilst the proportion in the inner zone is more than 5 per cent. Taking the stated dimensions of the zones, and assuming the extraction of the mineral to a maximum depth of 200 metres, the quantity of ozokerite obtainable in this locality would be more than two million tons.

Two products are obtained from the mines—viz., nearly pure ozokerite in fragments, and earth containing much ozokerite. The former is melted as it is, while the latter is subjected to the following operations in consecutive order.

1. Hand-picking or sorting.
2. Washing with cold water.
3. Washing with hot water.
4. Treatment with benzine and steam.

By hand-picking, all the larger fragments of ozokerite are sorted from the earthy matter; this work is performed at the pit's mouth by women, who are provided with small mattocks, by means of which the separation of the matrix is effected. After this, the earth, which still contains from 8 to 10 per cent. of ozokerite, is thrown into tubs of water, and stirred with shovels. Under these circumstances, the liberated ozokerite rises to the surface, and is skimmed off with a sieve. The earth, still containing from 4 to 5 per cent. of ozokerite, is then subjected to the action of boiling water, and the finer particles of the wax, aggregated by fusion, rise to the surface in the form of a black oily scum, which is removed from time to time. The fourth process, originally suggested by Van Haecht, consists in exposing the earth which, after treatment with boiling water, still contains from 1 to 1½ per cent. of ozokerite, to the solvent action of benzine. By this means nearly the whole of the remaining wax is dissolved, and by steam distillation the benzine is recovered. The ozokerite thus extracted commands a higher price than that which is obtained by either of the three preceding processes.

The separated ozokerite is melted and cast into loaves or blocks of the form of a truncated cone, and weighing about 50 or 60 kilos.

CHAPTER IV.

XVIII. The Refining of Petroleum in the United States.

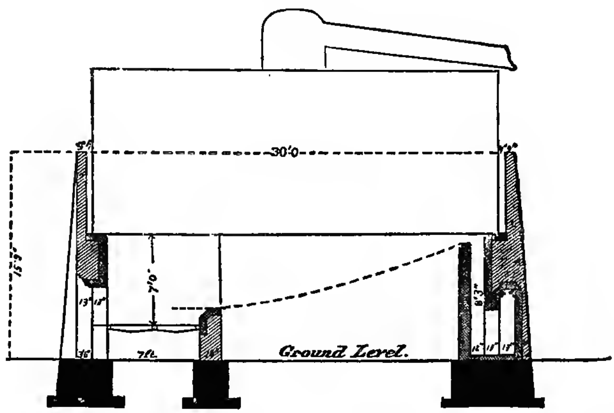
Some descriptions of crude petroleum of high viscosity are employed for lubricating purposes either in the state in which they come from the wells, when they are termed "natural oils," or after a certain proportion of their more volatile constituents has been removed by evaporation or distillation at a comparatively low temperature (vacuum stills being sometimes employed), when they are termed "reduced oils." These oils are sometimes purified by filtration through animal charcoal. Lubricating oils thus obtained are in some cases preferred to distilled products of similar density.

The bulk of the crude petroleum produced in the United States is, however, subjected to a process of fractional distillation, with the object of separating it into the following commercial products.

1. Naphtha or petroleum spirit of various grades.
2. Burning oils.
3. Lubricating oils.
4. Paraffin.

The first attempts to refine petroleum commercially in the United States were probably made in the year 1854, when a still, having a capacity of five barrels, was erected in Pittsburg, for refining the small quantity of crude oil obtained in the neighbourhood; but the scarcity of the raw material prevented for some time any important development of the industry. Burning and lubricating oils were subsequently made from bituminous coal in the United States in somewhat considerable quantities, but it was not until after the sinking of the Drake well, in 1859, that the distillation of petroleum on a large scale was commenced. Up to the year 1862, the stills commonly

FIG. 102.

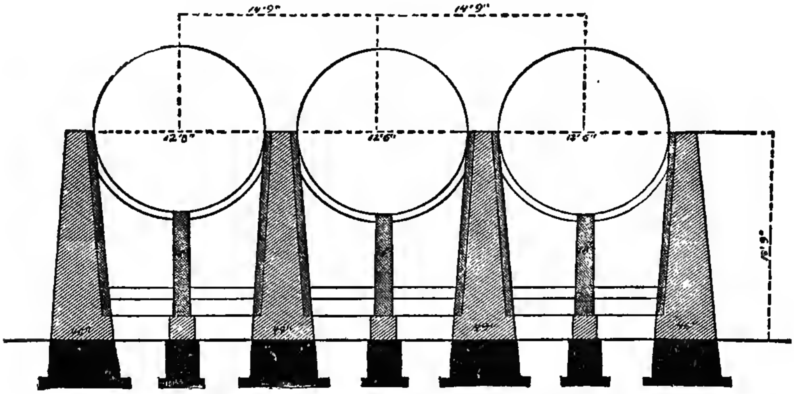


Longitudinal-vertical Section of Cylinder Still.

employed had a vertical cylindrical cast-iron body, a boiler-plate bottom and a cast-iron dome, with a goose-neck bolted on. The capacity of these stills was about twenty-five barrels, and the charge was distilled to dryness. At the present time the operation of petroleum distillation is divided into two distinct parts, which are commonly conducted at separate works. The first part consists in the separation of the crude petroleum into naphtha and burning oil, which constitute the distillates; and residuum, which remains in the still. The second part consists in the distillation of the residuum with a view to obtaining the lubricating oils and paraffin. In the distillation of the more volatile products, two forms of still are employed—namely, the horizontal cylindrical still, Figs. 102 and 103, and what is known as the "cheese-box" still, Figs. 104 and 105. The former description of still consists of a cylinder of boiler-plate (the lower half of which is commonly of steel and the upper half of iron), about thirty feet in length by twelve and a half feet in diameter, furnished with a dome, three feet in diameter, from which passes a vapour-pipe fifteen inches in diameter. This still is set horizontally in a furnace, and the upper half is usually exposed to the air. The "cheese-box" still, which is now much less used than the still already described, has a vertical cylindrical body, a dome-shaped top of iron boiler-plate, and a double-

curved bottom of steel-plate. It is thirty feet in diameter by nine feet in height or depth, and is set in a furnace on a series of brick arches. The vapour passes from this form of still through three vertical pipes into a vapour-chest, from which extend forty parallel 3-inch pipes. Wet steam

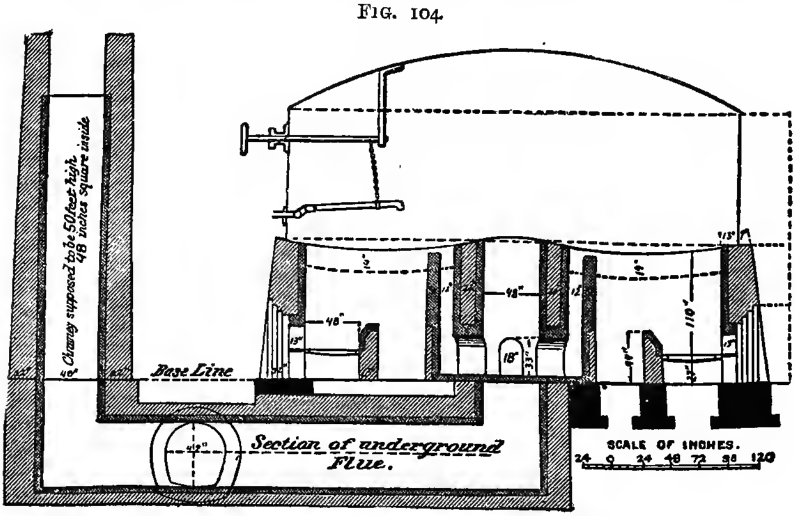
FIG. 103



Transverse-vertical Section of Cylinder Still.

is usually introduced into the exit pipes, so that it may mingle with the vapour of the oil. The working charge of the cylindrical still is about 600 barrels, and of the "cheese-box" still about double that quantity The condensers with which the stills are connected were at first copper worms,

FIG. 104.

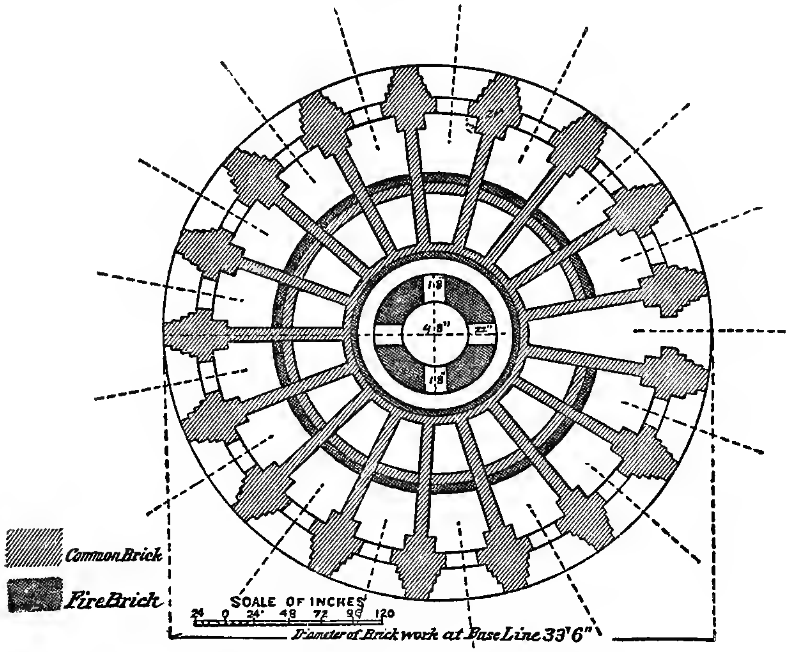


Vertical Section of Cheese-box Still-setting.

but now consist of iron pipes, usually straight, passing through tanks of cold water. A modern condensing arrangement may be described as consisting of a series of forty 3-inch pipes. In some cases, methods of fractional condensation designed to effect the more complete separation of the commercial products, are adopted.

Several attempts have been made to introduce the principle of continuous distillation, in the refining of American petroleum, but experiments in this direction do not appear to have been attended with satisfactory

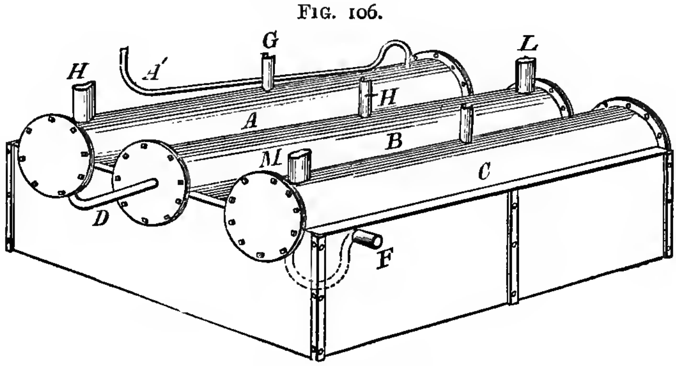
FIG. 105.



Horizontal Section of Cheese-box Still setting.

results. As long ago as the year 1860 a patent was granted in the United States to D. S. Stombs and Julius Brace of Newport, Kentucky, for "Improvements in the Distillation of Coal Oil," Figs. 106, 107, and 108.

FIG. 106.

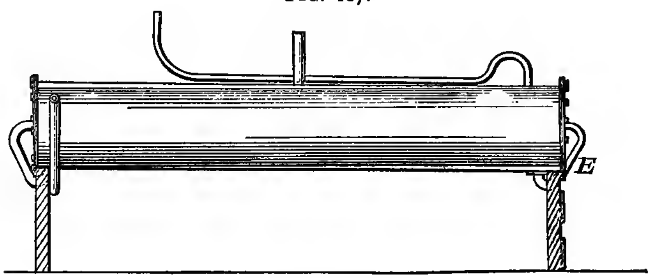


Perspective View.

The invention was described as "an improved method or process for separating the various products contained in Crude Coal Oil or other oils, by a continuous successive distillation, in such manner as that, on the operation being once commenced and a fresh supply of crude oil regularly

maintained, a simultaneous discharge of several qualities of oils and of other products by a simple process may be continued for an indefinite period of time, without any interruption, and without any care or trouble of removing the products from one receptacle to another, or of clearing the distilling vessel of the residuum, the same being performed by regular transference of the unfinished material from one retort to another, and the final discharge of the last waste product from the last retort in the apparatus without any mechanical aid whatever, the fluid discharging itself by the regular working of the apparatus." The nature of the said invention was further described in the specification as consisting "in separating from the crude oil the various products contained therein by volatilising it over

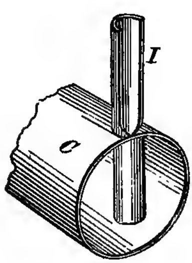
FIG. 107.



Side Elevation.

the surface, or upon, as it were, a bath of the fluid having a higher specific gravity, and heated to a degree of temperature at which the fluid to be separated from the crude oil volatilises. When the more volatile products become thus evaporated, the crude oil attains a higher degree of specific gravity, and sinking down commingles with the fluid of the bath, and while fresh crude oil is slowly poured in over the surface of the bath the unfinished material of the first bath passes gradually over upon another bath of the fluid having a still higher specific gravity and heated to a higher degree of temperature, and so on successively and continuously until the separation of the various products is completed. The final residuum discharges itself then from the bottom of the last retort." The arrangement consists of three stills, *A*, *B*, *C*, placed side by side but heated by independent furnaces. The three tubes, *G*, *H*, and *I*, one in the middle of each still, extend nearly to the bottom of the stills in each case, as in Fig. 108. They are closed at the bottom and are for the purpose of ascertaining the temperature of the oil in the stills. The crude oil is introduced into the upper part of the first still *A*, at one end, through the pipe *A'*, and from the lowest part of the opposite end of this still a pipe *D* passes into the end of the second still *B*, "at a point somewhat above the middle line of the said retort"; similarly at the lowest point of the opposite end of the second still *B*, a pipe passes into the third still *C*, which, in like manner, is also furnished with a pipe *F*, leading from the bottom at the end opposite to that at which the oil enters from the intermediate still. The products of distillation pass away through the vapour pipes *H*, *L*, and *M*, which are connected with suitable condensing apparatus. The inventors point out that a greater number of retorts may be arranged on the same principle, if it is desired to increase the number of grades of product. In working with three stills, it

FIG. 108.

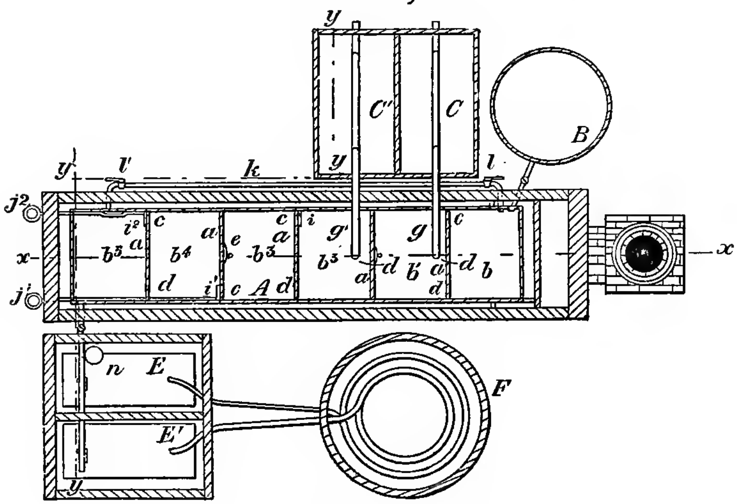


Sectional View.

is recommended that the temperatures of the contents of the first and second stills should be maintained at 170° to 200° and about 300° respectively (presumably degrees F. are meant), while the third still is to be heated to incipient dull redness.

In the use of this apparatus, the inventors direct that crude oil is to be delivered into still *A*, through the pipe *A'*, until the level of the oil reaches the point of discharge of the pipe *D*, into the retort *B*. The still *A* is then heated to 170°-200°, so as to vaporise the more volatile products, which pass through the pipe *H* to the condenser. When this volatilisation has been effected, a further quantity of crude oil is slowly introduced through the pipe *A'*. The crude oil already in the still having had its specific gravity raised by the elimination of its more volatile constituents, the fresh oil will float upon its surface and will there be subjected to a process of fractional distillation. As the level of the oil in still *A* becomes raised by the introduction of fresh crude oil, the heavier oil will begin to flow into still *B*, through the pipe *D*. Still *B* should then be heated

FIG. 109.



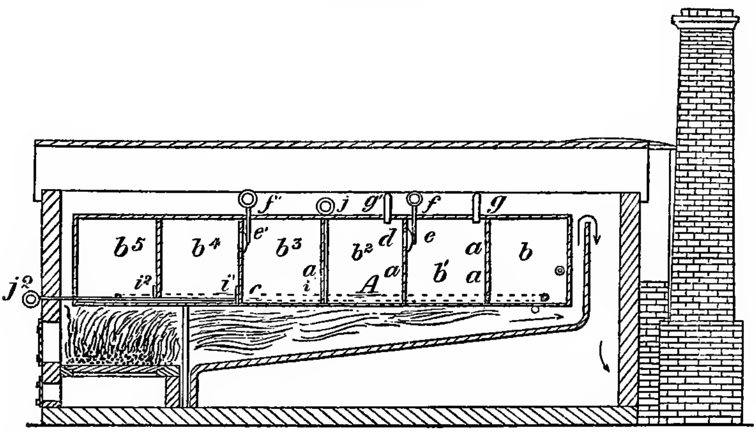
Horizontal Section.

to about 300°, and from it a product of higher boiling point than that obtained from still *A* will pass away, through the pipe *L*, to the condenser. When still *B* has thus become filled so that a portion of its contents is flowing into still *C*, the latter should be heated to incipient redness, and products of higher boiling point than those yielded by still *B* will, in like manner, pass through the pipe *M* to the condenser. When still *C* has become filled to a sufficient height the discharge of the residuum, through the pipe *F*, will commence, and the whole process will thereafter be continuous, as long as the supply of fresh crude oil to still *A* is maintained, and the stills are kept at the requisite temperatures.

In 1867, a patent was granted in the United States to A. H. Tait and Joseph W. Avis, of New York, for "Improvements in Apparatus for Distilling Petroleum, &c.," Figs. 109, 110, and 111, in the specification of which the apparatus was described as consisting "mainly of a still divided by one or more partitions into two or more compartments, which communicate with each other at the top by suitable openings for the vapours, and at the bottom by openings for the liquid." The openings at the top are provided with

gates or cocks "to shut off the communication and dividethe light from the heavy vapours so as to pass each oil into its appropriatecon denser." The compartments next to the fire are also provided with gates or valves to the openings at the bottom, so that on closing these the compartments may be

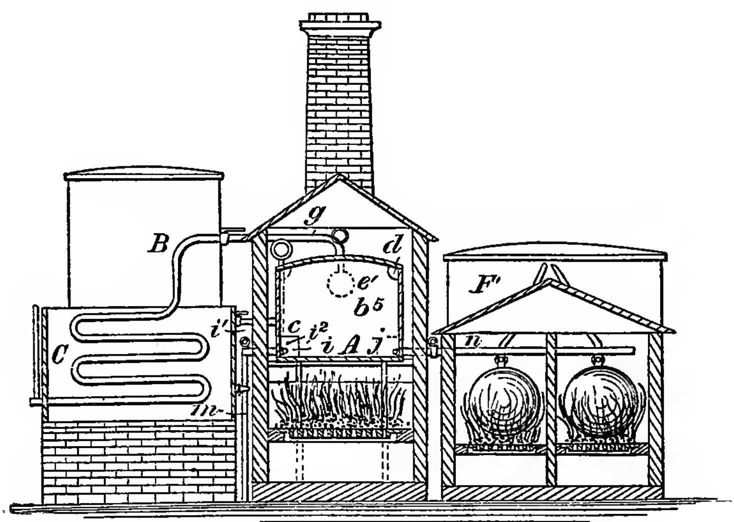
FIG. 110.



Vertical Section.

cleaned out without emptying the entire still. The crude oil is admitted to the compartment farthest from the fire, and the compartment nearest to the fire is connected by a pipe with coking retorts in which the refuse or "heavier parts of the oil are subjected to a final distillation."

FIG. 111.

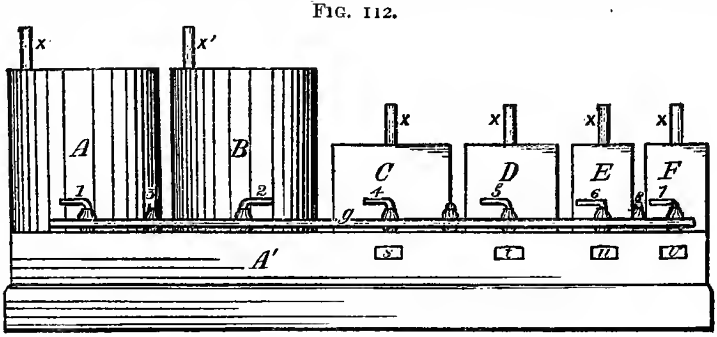


Cross Section.

A represents the still, divided by partitions *a*, into compartments *b*, b^1, b^2, b^3, b^4, b^5. The crude oil is admitted from the supply tank *B*, into the first compartment *b*, which is farthest from the fireplace, and it passes from this compartment to the succeeding compartments through apertures *c*, in the lower parts of the partitions *a*, the apertures being so situated that the

oil is compelled to run through the still in a zigzag course. In the upper parts of the partitions *a*, are openings *d*, for the passage of the vapour, and these openings are provided with valves e, e^1, operated by the handles f, f^1. From the compartments b^1 and b^2, rise pipes g, g^1, provided with stop-cocks h, h^1, and each of these pipes is connected with one of the condensers C or C^1. If the valve e is closed, the vapour from the first two compartments, b, b^1, passes through the condenser C, and the vapour from the other compartments through the condenser C^1. But if the valve e is opened, and the valve e^1 closed, the vapour from the compartments, b, b^1, b^2, b^3, can be made to pass through either of the condensers by adjusting the stop-cocks h and h^1. The apertures c, in the three last partitions a, are provided with gates i, i^1, i^2, operated by handles j, j^1, j^2. By closing the gate i, the liquid is prevented from passing into the compartments, b^3, b^4, b^5, which are nearest to the fire, and these compartments can be readily cleaned without interrupting the operation of the remaining compartments. Similarly by closing the gate i^1, the last two compartments b^4, b^5 can be cleaned, and if it is desired to clean the last compartment b^5 only, the gate i^2 is closed. The compartment b^5 is brought into direct communication with the compartment b by means of a pipe k, situated on the outside of the still. This pipe is provided with

FIG. 112.



Hill and Thumm's Still. Section.

stop-cocks l, l^1, and is connected with the discharge-pipe m. The liquid from the first compartment can thus be run directly into the last compartment, and the specific gravity of the product obtained from these compartments, as well as from the remaining compartments, can in this way be "regulated and equalised." The compartment b^5 communicates, through a pipe a, with the coking stills E, E^1, which are provided with a separate furnace. The vapour from the coking stills passes to the condenser F.

In 1870, Samuel A. Hill and Charles F. Thumm, of Oil City, Pa., obtained a patent in the United States for "Improvements in Apparatus for Distilling Hydrocarbon Oils," Figs. 112 and 113, the invention being described as consisting in "so constructing and arranging a series of stills with relation to each other that the oil will flow over the bottom of the stills in a thin and continuous sheet, with a different degree of heat applied to the bottom of each still; and in so arranging the connections between the several stills that the flow of oil through one or more of the stills may be cut off from the other stills in the same series."

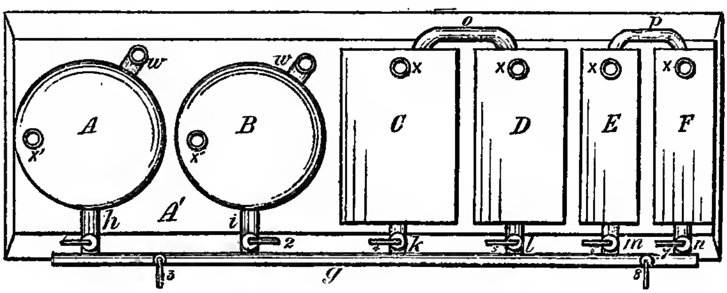
A and B are large separating and heating stills, used for the purpose of separating water from the oil, distilling off the very volatile hydrocarbons, and heating the oil. A^1 is a range of furnaces under the stills. A and B are supplied with oil through pipes w, and are furnished with vapour pipes x^1, which may be connected with condensers. Near the bottom of the stills A and B are two pipes, h and i, connected with the pipe g, which communicates

with the stills C, D, E and F, by means of pipes k, l, m and n. These pipes are provided with stop-cocks, as shown in the illustration. At the opposite end the stills C and D, and E and F, are respectively connected by means of the pipes o and p, which are placed close to the bottom. The stills C, D, E, and F, have vapour pipes, x, which may communicate with condensers.

In carrying out the process of distillation with this apparatus, oil is first introduced into the stills A and B, and the water separated from it. After the oil has been heated to about 49° C. (120° F.), the valves 1, 3 and 2, of the pipes h, g and i, are opened, and the oil is thus allowed to flow from the stills A and B over the bottom of still C, thence through the pipe o into still D, thence through the pipes l, g, and m, into still E, and thence through the pipe p into still F, passing over the bottom of each still in a thin and continuous sheet, and being subjected to a gradually increasing heat.

In 1870, a patent was granted in the United States to Samuel Van Sycles of Titusville, Pa., for a system of continuous distillation with "a series of stills in which the oil is maintained at a constant level by means of a tank, in which a float on the surface of the oil as it rises or falls automatically controls the flow of the oil." According to the late Mr. Benjamin J. Crew,* an apparatus constructed on this principle was put in operation in Buffalo, and the products actually placed on the market. The same writer describes

FIG. 113.



Hill and Thumm's Still. Plan.

a distillatory arrangement designed by Mr. James Cole, Jun., of Cleveland, Ohio, which may be broadly designated as a combination of continuous distillation and fractional condensation in a series of connected stills and condensers maintained at carefully graduated temperatures.

Although, as already stated, the principle of continuous distillation has not, so far at any rate, found favour in the United States, notwithstanding that a large number of patents, in addition to those mentioned, have been granted for various systems of applying it, the arrangements described are of more than historical interest, since the principle has long been practically applied with great success in the distillation of Russian petroleum, and Scotch shale oil.†

The crude petroleum, on reaching the refinery through the pipes of the transportation company, or in tank railway waggons, is placed in storage tanks, whence it is pumped or run by gravitation into the stills. A fire having been lighted in the furnace beneath the still, the temperature of the oil is raised slowly, and the more volatile hydrocarbons, constituting the crude naphtha, are distilled off, the distillate being sometimes collected in two fractions. When the density of the distillate flowing from the condensers has increased to about 62° B. (sp. gr. .729) the stream is diverted from the

* "A Practical Treatise on Petroleum." Philadelphia, 1887.

† The apparatus employed in Russia and Scotland respectively will be described in succeeding chapters.

naphtha tank into the kerosene tank, if the refiner is making an oil of 110° or 120° fire-test. If, on the other hand, he desires to obtain an oil of 150° fire-test, the collection of the kerosene is not commenced until the density has risen to about 56° B. (sp. gr. .753). In the former case that portion of the naphtha distilled which has a density between 70° B. (sp. gr. .700) and 62° B. is frequently collected separately, and the more volatile portion being subsequently removed from this fraction in a still by steam heat, there remains an oil which is added to the kerosene. In the latter case the portion of the distillate ranging in density between 62° B. and 56° B. is reserved to add to lower-test oil. The distillation of the kerosene is then usually continued until, in the case of the ordinary oil, the specific gravity of the whole product is slightly over .800, or in the case of the higher-test or water-white oil until the specific gravity of the product is about .790. In the distillation of the ordinary oil, it is now the practice to reduce the heat of the furnace when about two-thirds of the contents of the still have been volatilised, with the object of facilitating the process of "cracking," the time occupied in the distillation of the naphtha and ordinary oil being usually thus extended to three or even four days, with stills of the dimensions given. The percentage of naphtha and kerosene varies with the character of the crude oil, but the average yield of crude naphtha is usually about 12 per cent., and of kerosene of 110° fire-test about 75 per cent., in the case of the ordinary United States crude petroleum.

Of the higher-class kerosene, known as "water-white" oil, from 12 to 20 per cent. is obtained with a corresponding diminution in the yield of the ordinary kerosene. The fluid residue in the still, known as residuum, amounts to about 6 per cent., and when this has been run off there remains in the still a quantity of coke, representing from one to one and a half per cent. of the charge of crude oil, which has to be removed by hand before the still is re-charged. The crude naphtha is re-distilled by steam heat in cylindrical stills holding 500 barrels or more, provided with suitable arrangements for efficient condensation, and is sometimes separated into the following commercial products:

	Density Baumé.	Sp. Gr.	Use.
1. Rhigolene or cymogene	90°	.636	For surgical purposes as a local anæsthetic.
2. Gasolene	88° to 86°	.642 to .648	For air-gas machines.
3. Boulevard gas fluid	76°	.678	For street naphtha lamps
4. Prime city naphtha (benzoline)	73° to 68°	.690 to .707	For sponge lamps, &c.
5. Benzine	62°	.729	For oil-cloth and varnish making.

The percentage of these products varies, but as a rule amounts to about 25 per cent. of the first three collectively; rather over 25 per cent. of the fourth, and about 40 per cent. of the fifth. Of rhigolene, the crude naphtha frequently yields but 0.1 per cent., and of gasolene from one to three per cent.

By some refiners the products are classified as follows:

		Density Baumé.	Sp. Gr.
Petroleum ether.	1. Cymogene	108°	.590
	2. Rhigolene	94° to 92°	.625 to .631
	3. Gasolene	95° to 80°	.635 to .666
Petroleum spirit.	4. C. Naphtha (benzine-naphtha)	76° to 70°	.678 to .700
	5. B. Naphtha	66° to 65°	.714 to .718
	6. A. Naphtha (benzine)	59° to 58°	.741 to .745

Of these products, Mr. Alfred H. Allen ("Commercial Organic Analysis," vol. ii.) states that cymogene consists chiefly of butane (C_4H_{10}), and is condensed by artificial pressure; rhigolene of pentane (C_5H_{12}) and isopentane; and gasolene of hexane (C_6H_{14}) and isohexane. The less volatile products consist of heptane, octane, and the higher homologues of the paraffin series of hydrocarbons, with isoparaffins, olefines, and traces of the benzene series of hydrocarbons. The fraction having a specific gravity of .685 to .690, is sometimes termed ligroïn. The "benzin" of the United States Pharmacopœia is the portion of the distillate from American petroleum having a specific gravity between .670 and .675, and boiling between 50° and 60° C. (122° and 140° F.). The "petroleum-benzin" of the German Pharmacopœia consists of the colourless, non-fluorescent portions of petroleum having a specific gravity of .640 to .670, and distilling almost entirely between 55° and 75° C. (131° and 167° F.). "Petroleum-naphtha" is required by the New York Produce Exchange to be water-white and sweet, and of density from 68° to 70° Baumé (sp. gr. .707 to .690).

The time occupied in working the charge is about 48 hours. Some of the naphtha products are treated with acid and alkali, in the manner hereafter described in the case of the kerosene, with the object of deodorising them, one-half per cent. of acid being usually found sufficient and the agitation being effected by a revolving paddle.

Petroleum spirit is a very volatile and inflammable, colourless, mobile liquid, of characteristic and not unpleasant odour when properly refined. It is but very slightly soluble in water, but dissolves in about six parts of rectified spirit. Most of the fixed oils, naphthalene, paraffin, &c., are freely soluble in it, and it mixes in all proportions with amylic alcohol, ether, chloroform, benzene, and oil of turpentine. Petroleum spirit is not a liquid of uniform chemical composition, and the specific gravity of its vapour varies accordingly, but may roughly be said to be three or four times that of air. One volume of the liquid ordinarily gives about 141 volumes of vapour at common temperatures, and one volume of vapour will render about 113 volumes of air inflammable, or about 35 volumes of air strongly explosive.

The aim of the refiner has always been to produce from the crude petroleum the largest yield of burning oil of satisfactory quality—that is to say, of an oil containing neither, on the one hand, so large a proportion of the lighter hydrocarbons that the flashing point or fire-test is below the required limit; nor, on the other hand, so much of the heavier hydrocarbons that the oil does not burn freely in the lamp. At first the distillation was so conducted as merely to effect a separation of the hydrocarbons existing in the crude petroleum, but for many years past the process termed "cracking" has been largely adopted, and the yield of kerosene has thereby been greatly augmented, the intermediate hydrocarbons of the crude oil, which have too little viscosity to admit of their advantageous use as lubricants, being broken up and converted into hydrocarbons of less density which may be allowed to pass into the kerosene distillate without injury to the burning quality of the latter. The process of cracking is carried out by conducting the operation of distillation so slowly that the less volatile hydrocarbons become condensed in the upper part of the still, which, as already stated, is exposed to the air, and falling back into the oil are heated to temperatures above their boiling points, when the required dissociation occurs, the gaseous products evolved being utilised as fuel.*

The kerosene distillate obtained in the manner described has an empyreumatic odour and quickly becomes darkened in colour. With the object of removing these defects, it is treated with about 1½ per cent. of oil of vitriol. The treatment is effected in cylindrical iron vessels (sometimes lead-

* This subject is further dealt with in § XXII p. 204.

lined), termed agitators, 40 feet or more in height, by 20 feet or more in diameter, and holding from 1200 to 1800 barrels of oil. The distillate, which should not have a temperature much above 15.5° C. (60° F.), and should be perfectly free from water, having been pumped into the agitator, the acid, which is forced to the top of the tank by air-pressure, is showered into the oil through a perforated leaden pipe. A blast of air is then admitted at the base of the tank and the contents are actively agitated, the acid being thus brought thoroughly into contact with the oil. Some refiners introduce first a very small quantity of acid, agitate the oil for a short time and draw off the acid, which quickly subsides to the bottom of the agitator, thus effecting the removal of water held in suspension in the oil. About half of the remaining acid is then added, agitation continued for 45 minutes, the acid being then allowed to settle for an hour and drawn off, and the final portion of the acid added. After a similar period of agitation and rest the acid is again drawn off, and water is allowed to flow down through the oil in fine streams issuing from a perforated pipe running round the upper edge of the tank. This washing is continued for four or five hours, the water flowing off concurrently from the bottom of the agitator until the acid has been almost all removed. A final washing with water is then effected by closing the outlet at the bottom, and starting the air-blast, and this water having been drawn off, the oil is lastly agitated for about 30 minutes with 1 per cent of a solution of caustic soda (strength 12° B.). Occasionally the oil is subjected to another washing with water after the alkali treatment. The acid used in the process is frequently recovered and concentrated for further use. From the agitator the kerosene is run into a shallow rectangular tank, provided with a steam or hot-water coil for raising the temperature in cold weather. There any water present is deposited and the oil becomes bright. In connection with the settling tank is an arrangement for "spraying." This operation consists in forcing the oil in fine streams through small orifices in pipes placed above the tank, some of the more volatile hydrocarbons being eliminated and passing into the air, and the flashing-point of the oil, if too low, being raised to the required point. From the settling tanks the oil passes to the barrelling or canning tanks. The burning oils chiefly manufactured in the United States are of the following grades:—Fire-test 110° F., Abel-test 70° F.; Fire-test 120 F., Abel-test 73° F.; Fire-test 150° F. The 150° fire-test oil is nominally "water-white" (colourless), and the other oils range in colour from "prime-white" to "standard-white" (straw colour to pale yellow). The rules of the New York Produce Exchange require that refined petroleum shall be standard white or better, with a burning-test of 110° F. or upwards, and a specific gravity not below 44° Baumé, United States Dispensatory Standard (not above .811 specific gravity). Until within the last few years, the greater part of the oil exported from the United States was of 110° fire-test, the United Kingdom, however, taking 120° fire-test oil. Since the introduction of the Abel system of testing, a large proportion of the oil has been manufactured of 70° Abel-test for shipment to the Continent of Europe; while for use in this country, the oil is made of 73° Abel-test. The water-white oil of 150° fire-test is considerably lower in density than the ordinary oil, the specific gravity now usually ranging from .782 to .786. Besides these grades, there is manufactured, to a comparatively small extent, a burning oil of 300° F. fire-test, and density from .825 to .830, which, under the name of Mineral Sperm Oil, or Mineral Colza Oil, or Mineral Seal Oil, is employed in cases wherein the use of a more readily ignitable oil might be objectionable. This oil is stated to be preferably composed of the distillate from the crude oil, ranging in density from 40° B. to 32° B. (sp. gr. .8235 to .8641), treated

with sulphuric acid in the proportion of four ounces of acid to one gallon of oil, washed with solution of caustic soda, and then redistilled over soda lye. Of such oil about 10 per cent. may be obtained from the crude petroleum.

The residuum drawn from the kerosene still has a density of about 19° B. (sp. gr. .942). It is allowed to stand for several days, in order that the fine particles of coke may subside, and is frequently conveyed from the kerosene refinery to the lubricating oil refinery in bulk barges. The distillation of the residuum is effected in cylindrical stills (commonly constructed of steel) holding 260 barrels. The form of condenser already described in connection with the distillation of kerosene is employed, but the water with which the pipes are surrounded is maintained at a temperature high enough to prevent the solidification of the paraffin. In some instances, air condensers, consisting of pipes eight or ten inches in diameter, rising slightly as they pass from the still, and provided with outlets at intervals, are employed. Superheated steam is passed into the stills during the distillation, the object being to prevent dissociation, as far as possible, during the volatilisation of the lubricating oils and solid paraffin, instead of promoting this action, as in the case of the distillation of the kerosene. The charge is distilled to dryness, the process occupying about 30 hours, and the coke which remains in the still usually amounts, with the loss in gas, to about 12 per cent. of the residuum. The first portion of the distillate, of a density of about 38° B. (sp. gr. .833) and amounting in some cases to as much as 20 or 25 per cent., is frequently reserved for redistillation in admixture with crude oil. The remainder of the distillate is commonly collected in at least two fractions, the proportions and specific gravity of which depend upon the description of lubricating oil required. In many cases, the second fraction consists of an oil of density 31° B. to 33° B. (sp. gr. .870 to .859) of which about 25 per cent. may be obtained, and the remainder of the distillate will then consist of an oil of density about 22° B. to 24° B. (sp. gr. .921 to .909). The second fraction may be either subdivided by redistillation, or made into what is termed neutral oil (after separation of the paraffin by cooling), by filtration through bone-black, to remove colour and odour, and exposure to the air in shallow tanks, with the object of diminishing the fluorescence. Neutral oil, which generally has a fire-test of 300° to 350° F., is employed in admixture with a fixed oil (to give it additional viscosity), as a lubricant for light machinery, such as spindles. The third fraction is the "stock" for engine oil, and when it is desired to produce an oil suitable for heavy machinery, the percentage of this fraction is diminished (the yield of the second fraction being correspondingly increased) so as to produce an oil of density 21° B. or 20° B. (sp. gr. .927 to .933). The fire-test of the oil obtained, ranges from 177° C. (350° F.) upwards. In certain cases, the distillate is reduced by carefully distilling off, with the aid of superheated steam, a portion of the more volatile hydrocarbons (after removal of the paraffin by cooling), the residue in the still being afterwards filtered through bone-black. Whatever be the proportions in which the lubricating oil distillate is divided, the first stage in the process of refining consists in the treatment of the oil with from three to five per cent. of its volume of sulphuric acid, followed by the usual washing with water and caustic soda solution, the oil being maintained throughout at such a temperature as to prevent the paraffin from crystallising out. To obtain the solid hydrocarbons, the oil is then exposed to a low temperature. The cooling was formerly effected somewhat rapidly, but it has been found that slow cooling favours the formation of large crystals, and facilitates the expression of the oil. It is therefore now the practice to operate upon a considerable bulk (as much as 3000 gallons) and to extend the chilling over a period of abou 26 hours. The cooling is effected, in modern works, in a cellular tank, the oil cells alternating with cells through which a solution of

magnesium chloride, brought to a sufficiently low temperature by means of an ammonia refrigerating apparatus, circulates. The chilled oil is removed in a solid, or semi-solid mass, placed in strong canvas bags, and subjected to cautiously applied hydraulic pressure, at a temperature of 4.5° C. (40° F.). To effect a further separation of oil, the press cakes are broken up, melted, and re-crystallised, and subjected to a second pressure of about 200 lbs. per square inch, at a temperature of 21° C. (70° F.). The residuum yields thus about 9 per cent. of paraffin "scale," or crude paraffin wax. The paraffin scale separated from oil of sp. gr. .905, has a melting point of about 52° C. (125° F.) (American test), and that from oil of sp. gr. .885 a melting point of about 47° C. (117° F.). The further purification of the paraffin is effected by crystallisation from petroleum spirit, and filtration through animal charcoal (bone-black), or by fractional fusion (the material, cast into thin slabs, being exposed to a temperature just sufficient to cause the melting and draining out of the more fusible hydrocarbons), followed by the charcoal treatment.

Paraffin chiefly consists of a mixture of hydrocarbons of the paraffin series, C_nH_{2n+2}, together, doubtless, with olefines, the specific gravities, melting points, and boiling points of the hydrocarbons of which it is composed, varying within somewhat wide limits. When purified, paraffin is a white, or bluish-white, translucent, waxy solid of lamino-crystalline structure, devoid of taste and smell, and characterised by chemical indifference (*parum affinis*). The specific gravity of paraffin obtained from United States petroleum, is usually about .908 at 15.5° (60° F.), or about .750 at 100° C. (212° F). Beilby has shown that paraffin in solution has practically the same specific gravity as when in a state of fusion. At a temperature below its melting point it becomes plastic, a characteristic which is sometimes very inconvenient when the material is used in the form of candles, but this can be neutralised to some extent by the admixture of a small percentage of stearic acid. When two blocks of paraffin are struck together, a sharp metallic sound is emitted, especially if the melting point of the paraffin be high. Exposed for some time, under slight pressure, to a temperature above its melting point, paraffin undergoes a molecular change, and becomes transparent, but upon a change of temperature, or upon being struck, the translucent appearance returns. Paraffin is freely soluble in petroleum, or shale oil and spirit, in ether, in benzene, and in essential oils. It is sparingly soluble in hot absolute alcohol, but separates on cooling. It is insoluble in rectified spirit and in alcohol. When boiled with concentrated nitric acid, paraffin is oxidised with the formation of succinic and cerotic acids. Paraffin is also oxidised when heated with potassium permanganate, and sulphuric acid. At a high temperature, it is slowly attacked by concentrated sulphuric acid; chlorine also, when passed into melted paraffin, attacks it gradually. When heated with sulphur, paraffin is decomposed, sulphuretted hydrogen being evolved, and carbon deposited.

Paraffin is chiefly consumed as a candle material, but is also largely employed to communicate the required combustibility to wooden matches, and the writer has seen it applied in a thin coating over the heads of matches to render them waterproof. The use of paraffin for strengthening and waterproofing woollen fabrics was patented by Dr. Stenhouse. Paraffin is also employed for glazing frescoes and paper, for saturating gypsum figures, and to impart gloss to starched linen. The paper cases of dynamite cartridges are sometimes dipped in melted paraffin. It has also been recommended as a lining for beer barrels, and as a protective coating for the labels and stoppers of bottles containing corrosive fluids. It forms the basis of a preservative liquid for stone, is used in preserving eggs, and has been suggested to be similarly applied to meat, fruit, and flowers. Paraffin also forms a good electrical insulator. An application of the material was some time ago suggested by Mr. Joly of Dublin, who found that two blocks of

the material, placed in juxtaposition in the sight-box of the Bunsen photometer, form an excellent substitute for the ordinary disc. The writer has used this disc-substitute and finds it capable of affording very good results. Paraffin is also used in making models for ship-building, in consequence of the facility with which the material is moulded.

Towards the end of the distillation of the residuum, dense vapours issue from the still, and readily condense into a hard resinous substance of sp. gr. about 1.25, from which the hydrocarbons termed carbozene, carbopetrocene, and thallene have been obtained.

It has been already stated that certain kinds of crude petroleum are employed as lubricants either in the state in which they issue from the earth, or after they have been "reduced" by the removal of a portion of their more volatile constituents. Such crude oils usually range in density from about 28° B. to 31° or 32° B. (sp. gr. .886 to .870 or .864). The reduction is sometimes effected by simple exposure of the oil to the air on the surface of water in shallow tanks; in other cases, by the action of steam heat in open vessels. Where, however, it is desired to obtain an oil of high viscosity (say an oil of density 26° B. (sp. gr. .897) and fire test 316° C. (600° F). or over), the crude material is carefully deprived of the more volatile hydrocarbons in a still, the removal of the vapour being assisted by the mechanical action of free steam. In this operation it is most important to prevent the cracking of the oil, as the "body" or viscosity of the product would be thereby reduced, and in some cases vacuum stills have been employed. The "cylinder oil" thus obtained is allowed to stand for several days at a temperature of 49° C. (120° F.) in order that particles of coke and other impurities may subside, and is sometimes partially decolorised by filtration through animal charcoal.

The foregoing is a general outline of the processes usually adopted in the manufacture of lubricating oils and paraffin from crude petroleum in the United States, but it will be readily understood that the processes are frequently necessarily modified to meet the special requirements of the refiner. The number of grades of mineral lubricating oils in the market is very considerable, but the following are among those most largely manufactured: Pale oils (sp. gr. .881, .903 to .907), Engine oil (sp. gr. .917 to .920), Dark machinery oils (Summer, winter and medium), Cylinder oils (Black and filtered).

There remains yet to be noticed one product of American petroleum, namely, vaseline, which may be described as an amorphous or comparatively uncrystalline semi-solid paraffin. This substance was first introduced into commerce by the Chesebrough Manufacturing Company, and the process of manufacture adopted by the company is stated to consist essentially in the removal by careful distillation, from selected crude petroleum, of the volatile hydrocarbons present, and the purification of the residue with animal charcoal. In order to reduce the temperature at which evaporation takes place, and diminish the tendency to dissociation, vacuum stills are employed. The process of manufacture which yields the best product consists in the efficient filtration of the material through animal charcoal, and subsequent exposure to superheated steam, but as very considerable quantities of animal charcoal are required for this process, some refiners first treat the raw material with sulphuric acid and bichromate of potassium. It is, however, difficult if not impossible to effect the complete removal of the acid, and as the vaseline might thus be left in a condition in which it would be liable to cause irritation of the skin in use, it is better to effect the purification by the use of charcoal only.

Vaseline is usually a pale yellow or colourless, translucent, fluorescent, semi-solid substance. It should be free from taste and smell, and devoid of crystalline structure. Its melting point is commonly from 40° C. (104° F.)

upwards, and its specific gravity at 100° C. (212° F.) is from 0.803 upwards. It probably consists, like paraffin wax, principally of a mixture of hydrocarbons of the paraffin series, the iso-paraffins from $C_{16}H_{34}$ to $C_{20}H_{42}$ being, apparently, the most prominent constituents, but olefines are doubtless also present in a notable proportion. Vaseline is insoluble in water, but dissolves in boiling alcohol, the material separating in flakes on cooling. American vaseline dissolves freely in ether, chloroform, benzene, carbon bisulphide and oil of turpentine.

The refining of petroleum in the United States is to a very large extent in the hands of the Standard Oil Company, who have a considerable number of refineries, some of which are of great size.

XIX. The Refining of Petroleum in Russia.

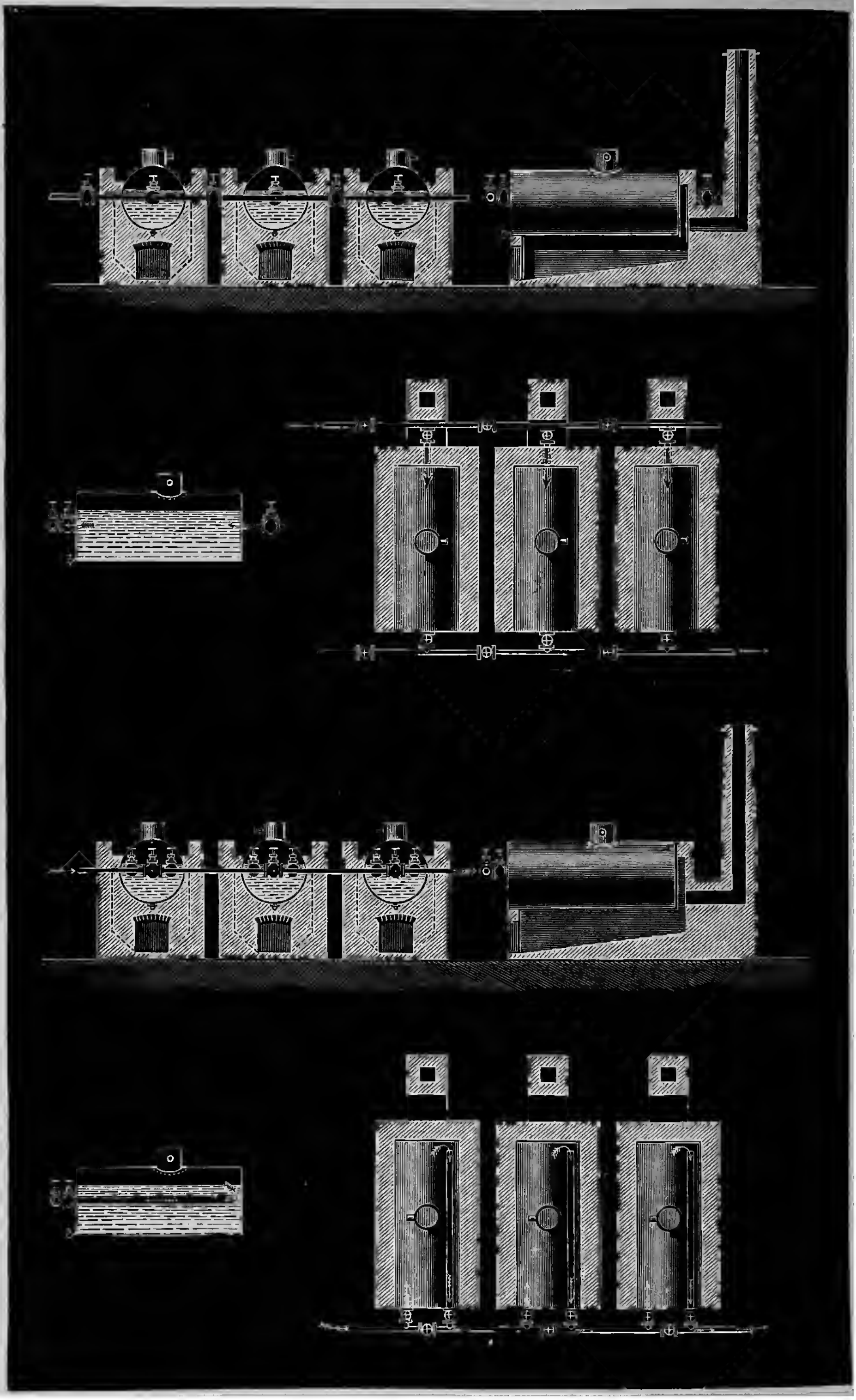
The refining of petroleum in Baku is conducted under various conditions, a portion of the trade being still in the hands of Tartars, who perform the operations in a most primitive and unsatisfactory manner, whilst the bulk of the business is carried on in large establishments provided with the most modern appliances. The primitive refinery consists in many cases of a single ten-barrel still heated by petroleum which is allowed to flow upon the hearth of the furnace and there burns with the production of much dense black smoke. Such a refinery is commonly destitute of any arrangements for the proper chemical treatment of the distillate, and the kerosene produced is of very inferior quality. At the great refinery of Messrs. Nobel Brothers (who were the first to erect at Baku a complete plant for the refining of the raw material on scientific principles) the distillation of the kerosene is effected on the continuous principle, the particular method of application which is adopted having been patented in Russia by Mr. Ludwig Nobel in 1882. The plant employed consists of a series of horizontal cylindrical stills, Fig. 114, usually arranged in groups of fourteen, through which the crude petroleum, previously heated, is caused to flow. The stills are heated to carefully regulated temperatures corresponding with the volatilising points of the products to be obtained from them. In this manner from the first still of the series, which is the least heated, the most volatile fraction is obtained, the boiling point and density of the products flowing from the successive condensers increasing with the temperatures to which the stills are subjected, until from the last still of the series, which is the most highly heated, the densest fraction which can advantageously be included in the kerosene is collected. From this last still, the residuum, which in Russia bears the name of *astatki*,* or that of *masut*, flows into a storage tank. The writer was informed by the late Mr. Ludwig Nobel that the process of continuous distillation is peculiarly suited to the refining of Russian petroleum, since the proportion of kerosene obtained is comparatively small, and the material flowing through the stills is thus not very greatly altered in character during the operation. The stills employed are 22 feet in length by 8 feet in diameter, and are heated with astatki blown into the furnace in a finely divided state by steam, the combustion thus being rendered smokeless. In the Nobel refinery at the time of the writer's visit in 1884, the products obtained from the kerosene stills were collected in three fractions, termed respectively—benzine (sp. gr. .754), gasolene (sp. gr. .787),† and kerosene (sp. gr. .820 to .822‡). Of the most volatile product, about one per cent. was obtained, of

* *Astatki* is the correct local name for the residuum, the term *masut* being properly applied only to crude petroleum which has lost its more volatile constituents by exposure to the air.

† It is now agreed to apply the more appropriate names of "light benzine" and "heavy benzine" to these two products.

‡ The specific gravity of the kerosene is now usually .825.

FIG. 114.



the next fraction about three per cent., and of kerosene, at the time of the writer's visit, about 27 per cent. Latterly, however, improvements in the method of distillation, coupled with a slight increase in the specific gravity of the product, have resulted in the yield of kerosene of good quality being in some instances increased to about 35 per cent. For the more volatile fractions there is but little demand, and much is burned to get rid of it. At the Nobel works, the kerosene is treated in lead-lined agitators, holding about 57,000 gallons, with about $1\frac{1}{2}$ per cent. of sulphuric acid, the oil being afterwards washed with water, and with a solution of caustic soda, as in the United States, the agitation being effected similarly by means of a blast of air. At other refineries, the crude oil is found to yield 20 per cent. of kerosene of sp. gr. .815 and flashing point 30° C. (86° F.), and as much as 38 per cent. of kerosene of sp. gr. .821 to .822 and flashing point 22° C. (71.6° F.). The standard flashing point of Russian kerosene for export is 28° C. (82.4° F.) (Abel-Pensky test), and the colour $2\frac{1}{2}$ (2 = Superfine white, and 3 = Prime white).

The capacity of the kerosene stills employed by many of the refiners is somewhat over 4000 imperial gallons, and three or four charges are "run" in the 24 hours, the lubricating oils being distilled in smaller stills.

The astatki or residuum which has a sp. gr. of .903 and upwards is largely used as fuel, but is also to some extent manufactured into lubricating oils of various grades. At one of the largest lubricating oil refineries the distillation of the residuum is conducted in horizontal cylindrical stills holding about 8000 kilos., the charge being worked off in 24 hours, and the distilled products being partly fractionally separated in air condensers, and partly in water condensers. The stills are heated with astatki and the distillation is assisted by the use of superheated steam. The process is usually continued until the distilled product has a specific gravity of .915 to .920, but in some cases the operation is suspended when the distillate has a specific gravity of .912 and a further quantity of astatki is added to the residuum which remains in the still, it being found that a denser product can thus be obtained. The distillate collected is then fractionated by another distillation, the first and second fractions, which are of the specific gravities of .865 and .875, being sold as "gas oil" and "cloth oil" respectively, as they are of too little viscosity to admit of their use as lubricants. The next fraction (sp. gr. .885 to .895) is sold as "spindle oil," the following (sp. gr. .895 to .910) as "machine oil," and the last (sp. gr. above .911) as "cylinder oil." From the material which now remains in the still, a product, which is semi-solid at common temperatures, and in this respect resembles American vaseline, is obtained by adding the fraction of .865 sp. gr. in the proportion of one part to three parts of the residue in the still, and carefully continuing the distillation with the aid of superheated steam. The purification of the lubricating oil distillates is sometimes effected by treating them with from 5 to 10 per cent. of sulphuric acid and afterwards with slaked lime, the process being completed by a final distillation. In other cases, the oil is simply treated with acid, and afterwards with dry potassium carbonate. At the Nobel works, the continuous process is also adopted in the distilling of lubricating oils, the stills, which are 22 feet in length and 10 feet in diameter, being arranged in groups of 9. The manufacture of paraffin scale is not carried on in Baku, the crude petroleum containing but a very small percentage (about $\frac{1}{4}$ of a per cent.) of this product, so that the lubricating oils require no separation of solid hydrocarbons by exposure to a low temperature to fit them to resist extreme cold without solidification. According to the late Mr. Nobel, Russian crude petroleum yields about 5 per cent. of cylinder oil besides upwards of 30 per cent. of other lubricating oils of less density, and one per cent. of vaseline, there remaining 14 per cent. of material suitable for use as liquid fuel, the

loss in the process being 10 per cent.* From Russian crude petroleum there is also obtained a heavy burning oil termed solar oil or pyronaphtha, which under the name of oleonaphtha, was first introduced by Messrs. Ragosine. Of such oil, having a sp. gr. of .865 and a flashing point (closed test) of 96° C. (205° F.) from 12 to 15 per cent. can be obtained from the crude material. The Ragosine Company manufacture the following grades of lubricating oils :—" Extra heavy cylinder oil" (sp. gr. .920), " Dark cylinder oil" (sp. gr. .918 to .920), " Cylinder and valve oil" (sp. gr. .912 to .915), " Engine machinery oil" (sp. gr. .905 to .907)

Russian lubricating oils have at common temperatures considerably greater viscosity than American lubricating oils of similar specific gravity, but suffer a greater diminution of viscosity when subjected to equal increments of temperature.

This is shown in the following table :—

VISCOSITY.—SECONDS FOR 50 C.C.

Results obtained with Redwood's Standard Viscometer.

Temperature Fahr.	1	2	3	4	5	6	7	8	9	10	11
50°	—	712½	—	620	—	145	425	1030	2040	2520	—
60	25½	540	177	470	—	105	295½	680	1235	1980	—
70	—	405	136⅘	366	—	90	225	485	820	1320	—
80	—	326	113	280	—	73	171	375	580	900	—
90	—	260	96	219¼	—	63½	136	262	426	640	—
100	—	213½	80½	174¾	—	54	111	200	315	440	1015
110	—	169	70½	147⅖	—	50	89½	153	226	335	739½
120	—	147	60½	126	—	47	78	126	174	245	531
130	—	123½	57	112	—	44¾	63½	101	135½	185	398½
140	—	105½	50¾	88⅖	—	41	58	82	116	145	317½
150	—	95½	49	75½	—	37½	52	70½	95	115	250
160	—	85	47½	70	—	—	46	63½	83½	93½	200
170	—	76	46	62	—	—	—	58	70½	77½	161
180	—	69	44½	56½	—	—	—	52½	61½	67½	134½
190	—	64½	43	53	—	—	—	47	56½	61	115½
200	—	58½	42	50⅖	54¾	—	—	42	48½	54	99¼
210	—	54	40¾	48½	—	—	—	40	—	—	85
220	—	50	39	47	—	—	—	38	—	—	77
230	—	47¼	36¾	45⅘	—	—	—	—	—	—	70½
240	—	45½	35¾	44⅗	—	—	—	—	—	—	64½
250	—	43¼	34¾	44	40	—	—	—	—	—	59¼
260	—	—	33¾	43½	—	—	—	—	—	—	54
270	—	—	32¾	43	—	—	—	—	—	—	48½
280	—	—	31$\frac{17}{20}$	41½	—	—	—	—	—	—	46½
290	—	—	30¾	41	—	—	—	—	—	—	44¼
300	—	—	30	38	—	—	—	—	—	—	42⅗
310	—	—	—	35	—	—	—	—	—	—	—
320	—	—	—	33⅘	—	—	—	—	—	—	—

1. Water.
2. Refined rape oil.
3. Sperm oil.
4. Neatsfoot oil.
5. Beef Tallow.
6. American mineral oil, sp. gr. .885.
7. " " , " .913.
8. " " " " .923.
9. Russian " " " .909.
10. " " " " .915.
11. Russian mineral oil, sp. gr. .884 (semi-solid at common temperatures).

* Mr. Chambers, U.S. Consular Agent, gave some time ago the following tabular statement of the results usually obtained :

Illuminating oil	30 per cent.
Lubricating oil	20 per cent.
Solar oil } Astatki }	35 per cent.
Waste	15 per cent.
	100

It will be noted that the specific gravity of Russian kerosene is considerably higher than that of American; the product, however, has a greater capacity for ascending the wick of the lamp by capillary attraction,* and although in most lamps a flame as large and as white as that yielded by good ordinary American kerosene, cannot be obtained from Russian kerosene, the size of the flame is, as a rule, better maintained throughout an extended period of burning.

The following classification of Russian petroleum products was adopted at the Petroleum Conference held at Baku in 1886 :—

1. Benzine, two sorts, namely :—

(*a*) Light benzine, colourless, used for manufacturing india-rubber goods, and distilled at a temperature not below 130° Centigrade, or 266° Fahrenheit.

(*b*) Heavy benzine, of a pale yellowish colour, yielding 10 per cent. refuse when distilled at a temperature as high as 150° Centigrade, or 302° Fahrenheit.

2. Kerosene, specific gravity 0.830; two sorts:—

(*a*) Safe, flashing point not less than 25° Centigrade, or 77° Fahrenheit.

(*b*) Unsafe, flashing point below 25° Centigrade, or 77° Fahrenheit.

3. Astralin, specific gravity 0.850, of a pale yellowish colour; flashing point less than 50° Centigrade, or 122° Fahrenheit.

4. Solar oil, specific gravity above 0.850, but not exceeding 0.880; flashing point not below 80° Centigrade, or 176° Fahrenheit; may be of very pale yellowish colour.

5. Lubricating oils, specific gravity from 0.880 and upwards.

6. Crude oil, specific gravity from 0.850 to 0.880; flashing point below 70° Centigrade, or 158° Fahrenheit.

7. Mazut, or crude oil deprived of volatile light substances by exposure to air; specific gravity above 70° Centigrade or 158° Fahrenheit; and residue, locally called "astatki"; flashing point not below 140° Centigrade, or 284° Fahrenheit.

8. The different petroleum products in a solid state, asphalte, ozokerit, &c.

9. Ceresine, paraffin, vaseline.

10. The different greases, varnishes, and mastics derived from petroleum.

XX. The Refining of Petroleum in Canada.

The distillation of crude petroleum is commonly commenced in Canada in horizontal two-flued cylindrical stills, 30 feet in length by 10 feet in diameter, provided with six 2-inch vapour pipes. The stills are heated with petroleum residuum as fuel, and take a working charge of 260 barrels. The distillation of the naphtha, of which the Petrolia crude oil yields about six barrels per charge, occupies from two to three hours. The heat is then increased, and about 80 barrels of kerosene distillate is obtained, the operation occupying about ten hours. The first portion of the kerosene distillate is usually collected

* This is clearly shown by the following figures which represent the respective quantities of the oils enumerated, which, in a series of experiments made by the writer, were removed from vessels of the same size by the capillary attraction of ordinary lamp wicks of two qualities in a given time.

	Sp. gr.	Best wick. grains.	Inferior wick. grains.
American kerosene (water white)	.790	205.0	104.2
Russian kerosene (ordinary)	.822	202.6	94.2
American kerosine (ordinary)	.800	146.0	69.7

separately, steamed to drive off the more volatile hydrocarbons, and afterwards added to the remainder of the kerosene distillate. The distillation being continued, about 80 barrels of a product known as "tailings" is then obtained in about seven hours. This product is fractionated by redistillation. At this stage steam is passed into the still through a pipe passing to the bottom and perforated at the lower end, and about 21 barrels of "gas-oil" distilled off. The residue is converted in smaller stills into lubricating oils and paraffin. The additional quantity of kerosene obtained by the redistillation of the tailings brings up the total yield of this product to about 42 per cent. of the crude oil. The gas oil is sold for the manufacture of illuminating gas. Canadian petroleum contains sulphur compounds in considerable quantity, and it is necessary to adopt a special method of treatment of the kerosene distillate for the removal of this impurity. The agitator in which the operations are conducted has usually a capacity of 465 barrels. To this quantity of distillate, two carboys of oil of vitriol is added, and the oil and acid are agitated together by an air-blast for twenty minutes. The tarry acid having been allowed to settle is drawn off, and seven carboys more of acid added. Agitation having been effected for thirty or forty minutes, the tarry acid is removed as before. Another similar treatment with seven carboys of acid follows, and occasionally a fourth addition of acid is made. The oil is next allowed to remain at rest for an hour, any acid which settles out being drawn off, and cold (or in winter slightly warmed) water is allowed to pass down through the oil in fine streams, this treatment being continued, without agitation of the oil, for half-an-hour, or until the dark colour which the oil assumed on treatment with acid is removed. The water is then draw off, ten barrels of solution of caustic soda (density 15° B.) is added, and agitation conducted for fifteen minutes. The caustic soda solution having been drawn off, 30 barrels of a solution of litharge in caustic soda is added for the purpose of removing the sulphur. This solution is made by dissolving caustic soda in water to a density of 18° B., and then adding as much litharge as is soluble. Agitation with this solution is continued for about six hours, or until the oil is thoroughly deodorised. About 100 lbs. of sublimed sulphur is then added, and the agitation is continued for another two hours. The oil having been allowed to settle all night, the litharge solution is drawn off, and the oil run into a shallow tank or "bleacher," where it is exposed to the light to improve its colour, and is, if necessary, steamed to drive off the lighter hydrocarbons, and raise the flashing-point to the legal minimum of 95° F. To raise the flashing-point from 73° F., Abel test (the English standard), to 95° is stated to involve in practice a loss of 10 per cent., the burning quality of the oil being at the same time impaired, and upon these grounds the Ontario refiners in 1886 petitioned for a reduction of the test standard. The average percentage yield of the various products is given in the following table:—

Naphtha	5
Kerosene	42
Gas-oil	8
Tar	25
Coke	10
Loss (including water)	10
	100

The rules of the Petrolia Oil Exchange provide that refined kerosene shall be of the odour "locally known as inoffensive," and shall "absolutely stand the test of oxide of lead in a strong solution of caustic soda, without change of colour." Three grades of kerosene are manufactured, the highest of which, termed "Extra Refined Oil," has a specific gravity of .800, and is

described as "water-white" in colour, the other grades being described as "No. 1 Refined Oil (prime white in colour)," and "No. 2 Refined Oil (standard white in colour)." The quality of Canadian kerosene has been greatly improved of late years, but notwithstanding the special process of refining adopted, the oil, though in many cases thoroughly deodorised and of good colour, still contains sulphur, and of course evolves sulphur compounds when it is burnt.

XXI. The Refining of Petroleum and Ozokerite in Galicia.

At the largest refinery in Galicia, which the writer visited in 1887, the kerosene is distilled in the usual horizontal cylindrical stills, the lower plates of which are of steel. These stills take a charge of 200 barrels, and are run twelve times per month, the petroleum residuum used as fuel being partly burned with the aid of a steam-blast (atomised), and partly in admixture with sawdust. The kerosene distillate is treated in lead-lined agitators, holding 500 barrels, with from 3 to 4 per cent. of sulphuric acid. At this refinery, which is situated at Peczenyzen, only the crude oil from the neighbouring field of Sloboda-Rungurska was distilled at the time of the writer's visit. This crude oil was stated to yield from 4 to 8 per cent. of "benzine" (according to the length of time that the material had been above ground), 58 per cent. of "standard oil" (sp. gr. .813 to .816, and flashing point 22° C. or 71.6° F.), 4 per cent. of "inflammable oil," and $2\frac{1}{4}$ to $2\frac{1}{2}$ per cent. of solid paraffin. The paraffin oil, which was distilled from the residuum of the kerosene stills in forty-barrel stills with steel bottoms, was "chilled" by mixing it with crushed ice, and the paraffin was obtained by subjecting the semi-solid mass to pressure in Canadian presses, which are wooden lever presses of simple construction. Lubricating oils were not manufactured at this refinery, and the expressed oil was accordingly used as fuel. The capacity of the refinery was 7000 barrels of kerosene per month.

At a smaller refinery which the writer visited in Ustrzyki, the crude oil was distilled in wrought-iron pot stills, 6 feet in diameter and 5 feet in height, the condensers bring worms of 3-inch iron pipe. At this refinery various classes of crude oil were distilled, and the percentage of products obtained was as follows:—

	Wietzno crude.	Ropienka crude.	Polana crude.
Benzine	15	10	5
Saloon oil	30	35	40
Second grade oil	8 to 10	10	15

The residue was further distilled in the same stills, and yielded about 20 per cent. of heavy oil, which was re-distilled. The final residue usually amounted to about 10 per cent. and the loss to about the same percentage. It appeared to be customary to mix the second grade of kerosene with benzine, and a burning oil was thus obtained which was inflammable at common temperatures, but which was nevertheless used locally to a considerable extent.

In the refining of ozokerite, the raw material, which has been separated from earthy matter by fusion, is treated with Nordhausen oil of vitriol, whereby a portion of the material becomes converted into a soluble sulpho-compound, and afterwards with charcoal.* The purified ozokerite, which then bears the name of ceresin, is separated as far as possible from the charcoal by pressure, and an additional quantity is obtained by exhausting

* The fine carbonaceous residue produced in the manufacture of potassium ferrocyanide is employed for this purpose.

the charcoal with benzine, which is afterwards recovered by distillation. There is thus usually obtained from the crude ozokerite from 60 to 70 per cent., or even more, of ceresin, which in some cases is afterwards coloured to imitate beeswax, and is largely used on the Continent, especially in Russia, as an adulterant of, or even as a substitute for, that substance. The melting point of refined ozokerit or ceresin usually ranges from 61° to 78° C. (142° to 172° F.), but notwithstanding this high melting point, the material when made into candles exhibits a tendency to gutter; it also burns with a smoky flame. For the production of the material of which candles are made, the ozokerite is subjected by Messrs. J. C. & J. Field, Limited, to a process of distillation, patented in 1870 by Field and Siemssen. Under this process, the ozokerite is melted, pumped into stills, and distilled in a current of superheated steam.* The distillate is "caked," pressed with naphtha, "cleared down" with fullers earth, and filtered. Under favourable circumstances, with good material, about 60 per cent. of white wax, of a melting point of 60° C. (140° F.), may thus be obtained. Candles made of this wax are especially adapted for use in high temperatures, as they are less liable to gutter and bend than ordinary paraffin candles. In addition to light oils, the crude ozokerite yields, under certain circumstances, a semi-solid product resembling vaseline, but less homogeneous. This product, known as yellow ozokerine, is used in ointments and pomades. By the action of Nordhausen sulphuric acid it is rendered white, and in that form is employed by French perfumers as a substitute for lard in the process of "enfleurage," the almost entire insolubility of the hydrocarbon in alcohol, and its non-liability to become rancid giving it a great advantage over the animal fat. The residue in the stills consists of a hard black waxy substance, for which at first no use could be found; but in 1875 Messrs. Field and Talling took out a patent for producing insulating electrical material by combining this black ozokerite with india-rubber by welding through rollers at a moderate temperature, and afterwards vulcanising the compound. This material, with certain modifications, has been introduced as "okonite" for the insulation of electrical cables. Okonite is not only a good insulator, but is remarkably flexible and tough. By a similar process, a form of the material known as "heel-ball" is manufactured. This is employed to impart a black polished surface to the heels and soles of boots; it is also very largely used by the Austrian Government for the leather work of cavalry and artillery. Natural ozokerite of good quality yields by Field's system of distillation about 60 per cent. of white *ozokerit* (melting point 60° C. or 140° F.), 30 per cent. of black ozokerite, and 3 per cent of *ozokerine*, the remaining 7 per cent. being represented by gas, light oil, and coke.

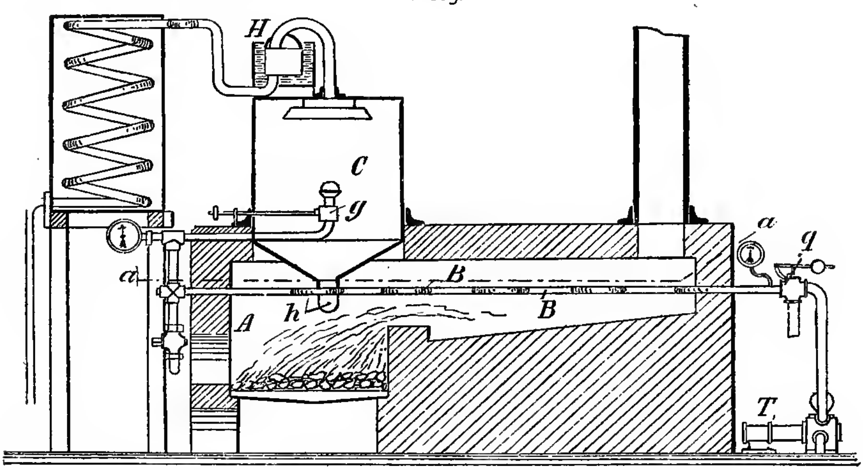
XXII. The Conversion of Heavy Oils into Liquid Hydrocarbons of Lower Specific Gravity.

In order to complete the review of the subject of petroleum refining, further reference is necessary to the changes effected by exposing the hydrocarbons to temperatures above their normal boiling-points. It has been already pointed out that the American petroleum refiner, by the adoption of the process known as "cracking" is enabled to obtain an increased proportion of kerosene from the crude oil, and the principle involved in this operation has been briefly referred to. As far back as the year 1871, Messrs. Thorpe and Young, in a communication to the Royal Society "On the com-

* If the ozokerite is subjected to destructive distillation, it is very largely converted into gas, oil, and coke, but in the presence of superheated steam this decomposition does not take place to any important extent.

bined action of Heat and Pressure upon Paraffins," placed on record the fact that distillation under pressure was the means of breaking up paraffins into hydrocarbons of greater volatility and lower density. In their experiments, solid paraffin was employed, and the heat was so regulated that the pressure amounted to about 25 lbs. per square inch. From $3\frac{1}{2}$ kilos. of the paraffin these authors obtained about 4 litres of liquid hydrocarbons, of which 0.3 litres boiled below 100° C. (212° F.), 1 litre between 100° and 200° C. (212° and 392° F.), and 2.7 litres between 200° and 300° C. (392° and 572° F). It was further indicated that the mode of decomposition appeared to be general for the higher terms of that series of paraffins. The product thus obtained is a mixture of paraffins and olefines. For instance, the hydrocarbon $C_{20}H_{42}$ might be resolved into $C_5H_{12}+C_{15}H_{30}$, or C_6H_{14} + $C_{14}H_{28}$, or $C_7H_{16}+C_{13}H_{26}$, &c. Some years previous to the date of this communication to the Royal Society, however—namely, in 1865—Young obtained a patent for "Improvements in Treating Hydrocarbon Oils," which consisted in distilling the oil in a strong vessel provided with a loaded valve, the vapour being allowed to pass to the condenser through such valve, or

FIG. 115.



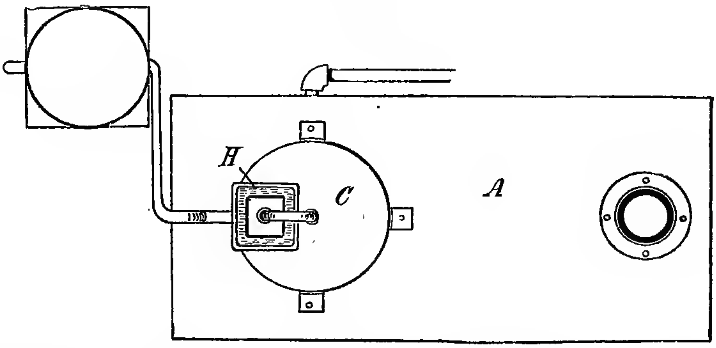
through a stopcock partially closed, so as to maintain the pressure. In working with shale-oil a pressure of about 20 lbs. to the square inch was recommended, and the result stated to be accomplished was the conversion of a large proportion of the oils originally operated upon into oils of lower specific gravity.

In 1887, Benton of Titusville, Pa., obtained a patent in this country (Haddan's Patent, 1922) for "improvements in the method and means of refining crude and refuse petroleum and the like," the process consisting in pumping the oil under considerable pressure (285 lbs., or more, to the square inch) through a series of pipes heated in a furnace, and then allowing it to escape into a vapour-chamber. By the adoption of this process the inventor claimed to be able to produce "lighter hydrocarbons from the refuse of petroleum oil, tar-oils, and other heavy mineral oils." The apparatus employed is shown in Figs. 115, 116, 117. It consists of a series of pipes *B*, arranged in a furnace *A*, by which the series is heated. The range of pipes communicates on the one side with a force-pump *T*, and on the other side with a vapour-chamber *C*. By means of the stop-valve *g*, the required pressure is maintained in the pipes. The vapour-chamber *C*, is heated, and

may, if desired, be partially exhausted. The vapour passes to the condenser *H*, and the unvolatilised liquid flows off at the bottom of the vapour chamber at *h*. In order to regulate the pressure in the pipes *B*, a suitably weighted check-valve, *q*, is placed between the force-pump *T*, and the pipes *B*.

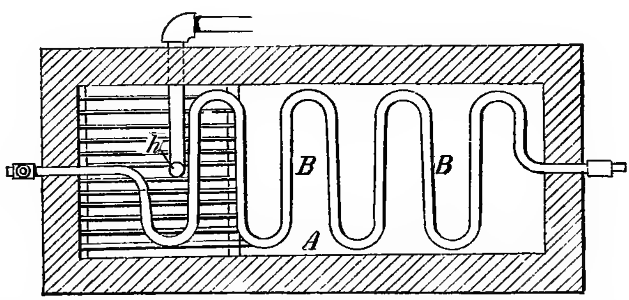
The process patented by Dewar and Redwood in 1889 consists in the use of a suitable still and condenser in free communication with each other—that is, without any valve or cock between them—the space in the still and condenser not occupied by liquid being charged with air, or carbonic acid gas, or other

FIG. 116.



gas, under the required pressure, and the condenser being provided with a regulated outlet for condensed liquid. An objectionable feature of the system of allowing the vapour to escape from the still to the condenser through a loaded valve—namely, the irregularity of the distillation—is thus removed, and the benefits of regular vaporisation and condensation under high pressure are obtained. The ordinary process of "cracking," which consists in allowing the less volatile portions of the vapour to become condensed in the stillhead, and fall back into the liquid below, is both slow and

FIG. 117.



comparatively ineffective, besides involving considerable waste of heat, but if desired the head of the still or retort employed in the Dewar-Redwood process may be so constructed as to produce partial condensation and thus cracking may be effected under high pressure. The apparatus for carrying out the process may be arranged in various ways, one form being shown in Figs. 118, 119, 120. Fig. 118 is a longitudinal, and Fig. 119 a transverse section. Fig. 120 is a sectional plan on the line *XX* of Fig. 118. *A* is a fireplace, with fire-door A^1, and ashpit door A^2, suited for regulating admission of air as required. Instead of a fireplace with grate for burning solid fuel, a burner for liquid or gaseous fuel may be employed. Above the combustion chamber

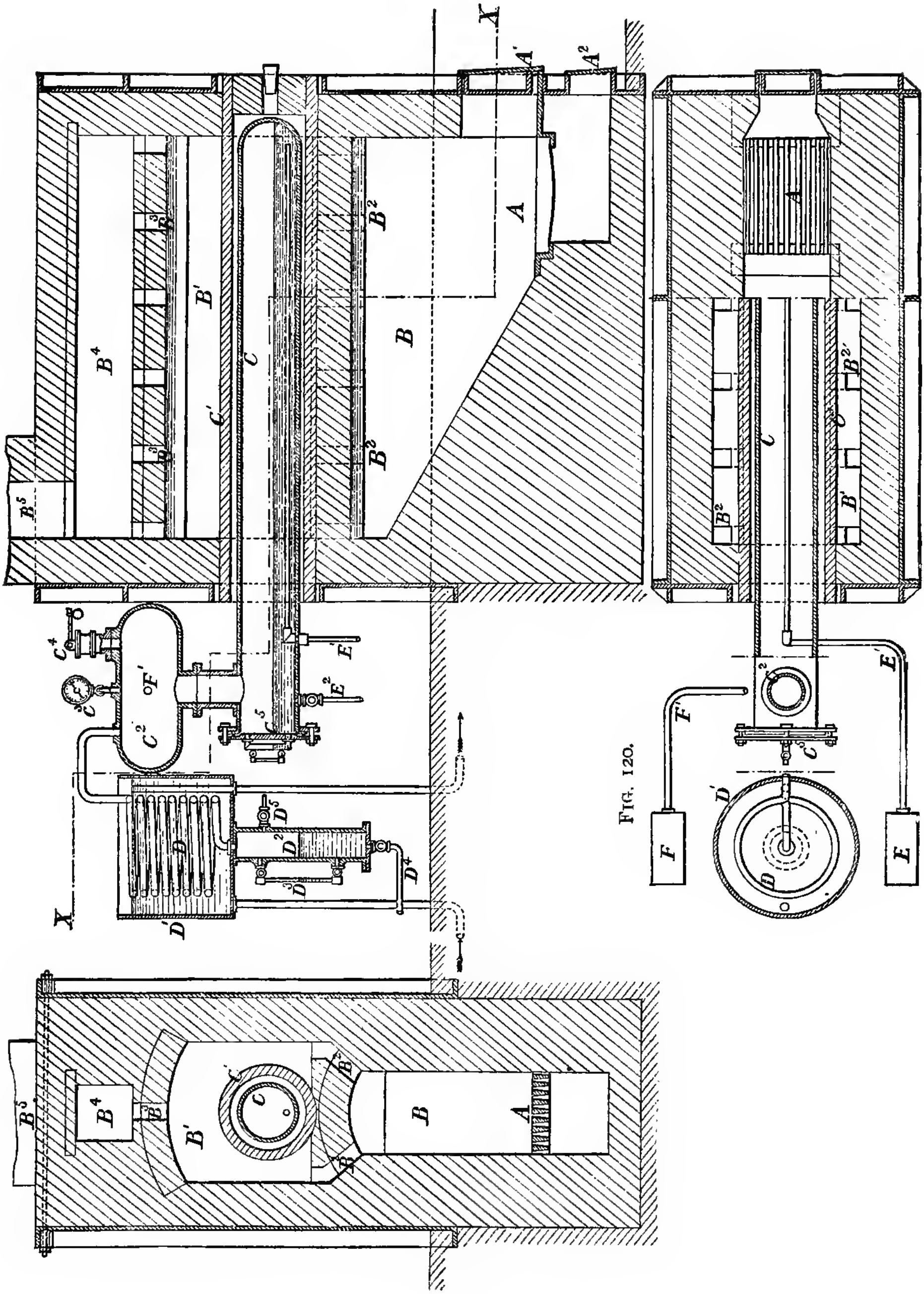


FIG. 118.

FIG. 116.

FIG. 120.

Dewar and Redwood's Apparatus for distilling Heavy Hydrogen oils under pressure.

B, is placed a metal retort C, which is enclosed within a refractory casing C^1, to protect the metal from excessive local heating. The encased retort is situated in a heating chamber B^1, into which the hot products of combustion ascend by side ports B^2, and from which they pass by central ports B^3, into a flue B^4, communicating with a chimney B^5. The front part of the retort C communicates freely with a stillhead C^2, provided with a pressure-gauge C^3, and safety valve C^4. The exposed end of the retort C is closed by a readily removable cover C^5, provided with a glass gauge to show the level of the liquid in the retort. D is a pipe-coil situated in a tank D^1, in which circulation of water is maintained. The upper end of the coil D communicates by a pipe with the stillhead C^2, and its lower end opens into a hollow column D^2, which is provided with a glass gauge D^3, and has at the bottom an outlet pipe D^4, furnished with a stopcock or valve. E is a pump for forcing the oil to be treated, by a pipe E^1, into the retort C, this pipe preferably extending nearly to the further end of the retort. By another pipe E^2, furnished with a cock or valve, the contents of the retort can be drawn off, or this pipe may communicate with a second retort, which in like manner may be connected with a third, so as to form a series of any required number. F is an air-compressing pump, by which air or suitable gas is forced by a pipe F^1, into the stillhead C^2, or it might be into any other part of the apparatus which is in communication with the stillhead. The retort C, being partly charged with oil by the pump E, and the spaces in the retort C, in the stillhead C^2, in the condensing coil D, and in the column D^2, being charged with air or gas to the desired pressure, the retort is heated, and the oil is vaporised under pressure. The oil vapour is condensed in passing through the coil D, and the liquid distillate which collects in the column D^2, is drawn off, either continuously or intermittently, into suitable receptacles, in which such gas as may be dissolved in the liquid is liberated and can be collected. By a pipe and cock, or a suitably loaded safety valve D^5, gas may be withdrawn from the space above the liquid in the column D^2. Although only one retort and condenser are shown, there may be several sets of these in communication with the oil and gas pumps, or with each other, suitable cocks or valves being provided in the communicating pipes, so that the several retorts may be worked simultaneously, or in rotation. From time to time, the cover C^5, of the retort may be removed to clear out residue. During the distillation, such of the vapour as may be condensed in the stillhead C^2, or such liquid as may prime up into the stillhead, flows back into the body of liquid in the retort. By regulating the heat and pressure to which the retort is subjected, the character of the distillate may be varied. The proportions of the several parts of the apparatus may be altered, and, if necessary, means of cooling may be applied to the stillhead C^2. With such an apparatus, intermediate and heavy oils may be readily converted to a considerable extent into lighter oils suitable for use in ordinary mineral-oil lamps, and even mineral spirit of low boiling point, capable of being employed for the carburetting of coal-gas, may be produced.

Crude petroleum, or petroleum distillate, of high density and boiling point, has not hitherto been found well adapted for use as a source of oil-gas, and the manufacture of gas oil from such materials has been carried out experimentally by means of a process patented in 1891 by Dr. Dvorkovitz, the Kerosene Company, Limited, and the Tank Storage and Carriage Company, Limited. In conducting this process, the crude petroleum, or other liquid hydrocarbon, is passed through an oil superheater of any convenient construction, in which it is heated to a high temperature, into a retort, where it is delivered through a perforated pipe. Here the oil is met by a current of superheated steam, also delivered through a perforated pipe, superheating being so effected that the temperature of the steam is higher than that of

the oil. The oil is thus separated into two portions, one consisting of oil vapour, and the other of "tar and other precipitated matters." The mixed oil vapour and steam pass through a dome or pipe of large sectional area to a condenser. The tar is passed through a second superheater to a second retort, where it again encounters superheated steam, the vaporised portion passing to a second condenser, and the tarry residue being removed in any convenient manner. As regards the method or process, the main principle claimed is the prevention of condensation in the retorts, the vapours being conveyed from the retorts to the condensers as rapidly as possible, while the high temperature is maintained; and in relation to the apparatus, the points of novelty are the employment of double sets of oil superheaters, retorts, and condensers, together with a steam superheater, and arrangements for intimately mixing the oil or oil vapours and steam in the retorts.

XXIII. Proportions of Commercial Products yielded by various descriptions of Crude Petroleum.

In the table on page 210 the proportions of some of the commercial products obtained from samples of crude petroleum examined by the writer are given. The process of distillation adopted was substantially the same in each case, and the results are therefore, from that point of view, comparative. In the distillation of these oils on the large scale, there would, in most cases, be a larger yield of kerosene, due to "cracking."

Of these oils, the sample from Upper Burmah contained the largest proportion of solid hydrocarbons (10 to 12 per cent.). The Assam petroleum also contained a considerable percentage. Among the other samples, those from Java, New Zealand, and Algeria may be described as rich in solid hydrocarbons. The samples from the United States, Canada, Galicia, Roumania, and Lower Burmah, gave a moderate yield of paraffin, but, on the other hand, those from Russia, Germany, Peru, and Mexico contained very little.

CHAPTER V.

XXIV. The Transport of Kerosene.

KEROSENE was for many years shipped from the refineries in the United States to the markets of the world only in the well-known oak barrels (which have a capacity of about 40 imperial gallons), or in the equally well-known "cases," which consist of two rectangular tins (holding four imperial gallons each) enclosed in a wooden box. The former package is employed where the dryness or heat of the climate does not interfere with its use, and the transport of so large a package is not attended with inconvenience; the more expensive case being reserved for use in the shipment of kerosene to the tropics or its carriage to comparatively inaccessible localities.

The barrels employed in the shipment of kerosene from the United States are now chiefly made by ingenious machinery with such rapidity that the Standard Oil Company are able at their Bayonne works to turn out from 10,000 to 12,000 finished barrels per day. In order to render the barrels impervious to the oil they are coated internally with a solution of glue, in the proportion of about 1 lb. of glue to three barrels. The barrels are filled from a rack provided with a series of pipes with self-acting valves, which stop the flow of the oil when the barrels have been filled to within one gallon of their contents, and the barrels are closed with wooden "shives" glued into the bungholes.

The manufacture of the tins is also carried on by machinery, the tin

Percentage of Commercial Products obtained from Crude Petroleum.

Locality.	Sp. Gr.	Percentage of Commercial Products.		
		Petroleum Spirit (Benzine).	Kerosene.	Intermediate and Lubricating Oils with solid Hydrocarbons.
Bradford, U.S.A.	.810	20.0	50.0	25.3
Parker (Clarion), U.S.A.	.797	21.0	74.0	—
„ (Karns City), U.S.A.	.789	32.0	64.0	—
Thorn Creek, U.S.A.	.802	21.0	74.0	—
Stoneham, U.S.A.	.802	15.0	75.0	6.6
Washington, U.S.A.	.788	18.1	71.1	0.8
Macksburg, U.S.A.	.829	10.5	49.5	35.5
Lima (Ohio)	.839	83.0		6.9
Wyoming	.910	2.0	24.7	50.9
„	.911	2.5	27.5	53.5
California (Pico Cañon)	.844	15.0	45.0	32.0
„ (Puente)	.880	12.5	23 0	42.6
Peru	.859	11.6	42.4	42.6
Ecuador	.928	5.5	14.5	68.1
Mexico	.874	nil	37.0	62.25
„	.882	nil	27.75	66.0
Canada (Petrolia)	.858	2.5	57.5	—
„ (Gaspé	.847	8.75	48.0	40.0
Russia (Balakhani-Saboontchi)	.872	6.3	32.50	59.1
„ (Surakhani)	.780	48.9	43.9	—
„ (Illski)	.853	20.0	40.0	35.0
„ „	.940	1.0	9.0	83.35
„ (Koudako)	.860	12.72	33.67	39.6
„ (Kertch)	.887	nil	28.0	70.5
Galicia (Sloboda-Rungurska)	.845	12.0	35.9	41.6
„ „ „	.860	8.8	37.4	40.0
„ (Ustrzyki District)	.846	9.6	38.4	44.3
„ „ „	.912	2.6	17.4	58.6
„ (Harklowa)	.901	7.5	32.5	51.8
„ (Lenczyn)	.875	8.4	36.5	50.3
Roumania	.859	nil	18.9	80.6
„	.845	28.85	26.3	42.5
„	.860	1.75	54.6	38.3
„	.839	nil	57.25	41.2
„	.890	nil	27.25	63.6
„	.896	2.0	25.1	67.5
„	.882	4.5	32.0	61.25
„	.846	21.26	33.88	40.28
„	.899	12.81	23.06	53.32
Germany	.872	1.94	35	59
Italy	.787	43.9	46.5	5.5
Upper Burmah (Yenangyoung)	.869	1.35	25.78	67.98
Lower Burmah	.834	9.0	57.5	32.0
„ „	.825	9.25	69.25	21.5
Assam	.858	11.18	35.97	48.8
Algeria	.921	0.75	28.25	60.75
Java	.881	nil	50.0	45.5
New Zealand	.829	nil	60.0	38.0

plates being cut, stamped, and bent in a series of machines, and the soldering of the joints being effected by automatic appliances of remarkable ingenuity. The wooden cases in which the tins are packed are put together by nailing

machines which drive in the whole of the nails for one angle at a single operation. 60,000 tin cans and 30,000 cases are turned out per day at the Devoe Works in New York.

Russia has, however, no adequate supplies of timber suitable for barrel-making, and accordingly, when the development of the petroleum industry in that country took place, Messrs. Nobel Brothers decided to ship the oil in bulk in tank steamers for conveyance from the refineries at Baku to the Volga, where it could be transferred to bulk barges and thence to tank waggons on the railroads. Previously to this, attempts had been made to ship petroleum in bulk from the United States, but these attempts not having been well planned were attended with failure. In these early efforts, the necessity for preventing oscillation of the oil, caused by the rolling of the ship, by keeping the tanks perfectly full (provision being made for expansion and contraction of the oil), appears to have been overlooked, and the discouraging results obtained were, no doubt, principally due to this.

The steamers first employed by Messrs. Nobel Brothers in the transport of kerosene in bulk were constructed at Motala in Sweden, and floated in two portions through the Russian canal system to the Volga, where the sections were united. These vessels are 250 feet in length by about 28 feet in width. They are furnished with a large tank occupying the whole of the fore-part of the vessel, and two cylindrical tanks aft, the engines and boilers being amidships. The aggregate capacity of the tanks is about 225,000 gallons. These steamships are of special interest as having afforded the first practical solution of the difficulties attending, or at one time considered to attend, the ocean transport of oil in bulk. They are loaded in four and a half hours, the oil being pumped on board through 8-inch pipes, and have proved perfectly seaworthy in the worst weather. The fuel used for steam generation is astatki, or petroleum residuum. The water at the mouth of the Volga being shallow, it is necessary to transfer the oil to bulk barges, which are towed up the river to Tsaritsin, a distance of 364 miles. There the oil is pumped into tank waggons on the railway for distribution throughout Russia, or in some instances for conveyance across the continent for the supply of other countries. At convenient centres large storage accommodation is provided in order that supplies may not run short during the period extending from November to April when the Volga navigation is closed by ice. By far the larger proportion, however, of the kerosene intended for shipment to other countries is transported in tank waggons from Baku to Batoum on the Black Sea by the Transcaucasian Railway, a distance of 560 miles. A portion of this line was originally carried over the Suram Pass, which has an elevation of 3000 feet, by a gradient as steep in places as 1 in 22; but the petroleum traffic over the line was conducted with difficulty, and the transporting capacity was by no means equal to the demand. A railroad tunnel under the Pass has, however, been recently completed, and previously a short pipe-line had been laid over the Pass, the carrying capacity of the railway being thus largely augmented. The laying of a pipe-line for crude oil from Baku to Batoum, or to the neighbouring port of Poti, has also been projected, and the construction of other railway lines which might advantageously be employed in the transport of the crude and refined materials is contemplated. Tank steamers of considerable carrying capacity are now regularly employed in the conveyance of kerosene in bulk from Batoum to various ports; there are also at Batoum factories for the manufacture of cans and cases, and large quantities of kerosene are packed there for shipment to the East and elsewhere. Concurrently with the development of the transport of the oil in bulk from Batoum, the same system has been successfully introduced in the export of kerosene from the United States. The first plan put into practical operation at the port of New York

was that which was devised by Mr. L. V. Sone, whose patent is of a comprehensive character and embodies no less than twelve claims. As exemplified in the case of a sailing vessel named the *Crusader*, the system consisted essentially in the employment of a number of cylindrical tanks, arranged horizontally, and varying in size so as to occupy as completely as possible the whole of the available space. Arrangements were provided for keeping the tanks, of which there were 45, quite full of oil, and each tank communicated with a steam-pump on deck, by means of which the whole cargo (equal to the contents of 5500 barrels) could be loaded or discharged in about ten hours. Tho principle of having a large number of tanks was subsequently adopted in the case of the *Andromeda*, this vessel containing 72 tanks, which instead of being cylindrical were principally rectangular. The capacity of this vessel was 684,641 American gallons. The further development of bulk transportation by sea resulted in the formation of some conflicting opinions as to the method of construction which should be adopted in the vessels employed in the trade. The provision of a small number of comparatively large tanks, with "trunks" or expansion tanks to ensure that the main tanks are always completely full, has, however, been generally accepted as preferable to that of a large number of small tanks, though it is obvious that the risk of the escape of a large quantity of the oil, in the event of injury to the ship by collision, is considerably increased by the adoption of the former principle of construction. Authorities have also been divided in opinion as to whether the tanks should be formed by the skin of the ship or should be independent. These and other details will be found fully discussed in a paper read by Mr. B. Martell, Chief Surveyor to Lloyd's, at a meeting of the Institution of Naval Architects on the 27th of July 1886.

There are now about ninety tank steamships afloat which have been specially built for the conveyance of petroleum in bulk. Many of these vessels are fine specimens of naval construction, and have a carrying capacity of over one million gallons of petroleum. The tanks, of which there are usually from seven to nine, occupy the central portion of the vessel, their sides and bottom being formed by the skin of the ship, and are separated from the boilers and engines, which are placed aft, by a coffer-dam or double bulkhead. Powerful pumps are provided by means of which the cargo can be rapidly discharged, and in some instances the tanks are furnished with steam-jet ventilating appliances for quickly removing any remaining oil vapour which might be a source of danger.*

The distribution of kerosene in the United States is very largely effected by means of tank-cars on the railroads, and tank-waggons drawn by horses on the highways, the oil being thus conveyed in bulk from the refineries to the shops of the retailers, and within the past two or three years this system has been adopted to a considerable extent in this country.

CHAPTER VI.

XXV. The Shale Oil Industry.

As early as the year 1694, Eele, Hancock and Portlock made "pitch, tar, and oyle out of a kind of stone," and in 1781 the Earl of Dundonald obtained oil from coal by destructive distillation. Paraffin was separated from wood tar by Reichenbach in 1830, and in the same year was produced

* When naked lights and hot rivets are to be used in the tanks in connection with repairing operations the careful testing of the atmosphere of the tanks becomes an important preliminary step. For this purpose the writer has patented, in conjunction with Professor Clowes, the application of a hydrogen flame in a lamp of suitable construction, together with apparatus for the collection of samples of the air (Section VI.).

by Laurent by the distillation of bituminous shale. Three years later Laurent suggested the working of the shale deposits of Autun as a source of mineral oil, and in 1839 burning oil and other products manufactured from this material were exhibited by Selligue. Paraffin is stated to have been made for sale by Reichenbach's process from wood tar by Mr. John Thom, of Birkacre, before the year 1835. Dr. Abraham Gesner claims to have been the first to produce illuminating oil from coal in America, and asserts that at public lectures delivered in Prince Edward's Island, in August 1846, he burned in lamps the oil thus obtained. The patents granted to Dr. Gesner passed into the possession of the North American Kerosene Gaslight Company, who manufactured the oil at their works at Newtown Creek, Long Island, and sold it, in 1854, under the name of kerosene oil. Dr. Gesner states that Messrs. Austen, the agents of the company, "found great difficulty in selling the oil. The refining process was not so well understood at that time as at present, and the odour was not agreeable. The beauty of the light obtained from it, however, was sufficient to gradually overcome the objection to it on the score of odour. Its supposed explosiveness was also urged against it by those interested in the camphine and burning fluids."

In 1849, experiments were made by Mr. Rees Reece and Sir Robert Kane to ascertain whether mineral oil and paraffin could be profitably produced from Irish peat, and in the following year the distillation of lignite for paraffin oil was commenced on the Rhine. In 1850, Mr. James Young obtained a patent for his process of producing paraffin oil by the destructive distillation of Boghead or Torbanehill mineral, and commenced the manufacture at Bathgate, Linlithgowshire, in conjunction with Mr. E. W. Binney and Mr. Meldrum.

In 1853, the United States Chemical Manufacturing Company began making lubricating oil from coal-tar at Waltham, Massachusetts; and, in 1857, the Downer Kerosene Oil Company first made mineral oils, for lubricating purposes, from Albert coal obtained from New Brunswick. Meanwhile, at New Bedford, Massachusetts, the distillation of Boghead mineral, imported from Scotland, was commenced, but cannel coals from West Virginia and Kentucky were soon substituted for the imported material. So rapidly did the industry develop that, in 1859, a single refinery on the Allegheny river had a distilling capacity equal to 6000 gallons of crude oil per diem.

The employment of Boghead mineral by Mr. Young as a source of oil, led to a notable lawsuit, which was instituted with a view of determining whether the mineral was "coal." It is worthy of note that in the course of this lawsuit attention was directed to the earlier patent of De Buisson for the distillation of "mineral schistus" at a low heat with a view to the production of oil. The ultimate decision was in the affirmative, but the question which was at issue soon ceased to be of practical importance, for in 1862 the supply of Boghead coal became exhausted, and since that date paraffin oil has been entirely produced in Scotland from the bituminous shales found below the coal measures, chiefly in Midlothian and Linlithgowshire. The aggregate amount of shale raised and distilled in Scotland at the present time is over two million tons per annum, the crude oil produced therefrom amounting to about sixty million gallons per annum. The following figures indicate the rate of growth of this trade during the years 1881 to 1890.

Estimated Quantity of Shale distilled in Scotland.

1881	912,171 tons	1886	1,968 500 tons
1882	985,488 „	1887	1,368,704 „
1883	1,130,729 „	1888	2,027,000 „
1884	1,469,649 „	1889	1,986,990 „
1885	1,757,700 „	1890	2,155,000 „

The following summary of the production of oil-shale, in the United Kingdom, was published by Mr. James Nicol, City Chamberlain of Glasgow.

Counties.	1880.	1881.	1882.	1883.	1884.
	Tons.	Tons.	Tons.	Tons.	Tons.
Edinburgh	372,994	451,018	478,593	458,206	640,753
Linlithgow	312,983	353,826	355 700	476,869	581,121
Fife	16,418	—	29,856	87.589	128,996
Renfrew	56,440	65,379	90,804	82,988	97,273
Lanark	28,830	30,293	25,606	16.318	9,752
Ayr	6,172	6,533	4,929	4,242	7,219
Stirling	—	5,122	—	4,517	4,535
Scotland	793,837	912,171	985 488	1,130 729	1 469,649
England and Wales	43,968	46,048	36,428	37,214	49,222
Total production in the United Kingdom.	837,805	958,219	1,021,916	1,167,943	1,518,871

The following table gives the names of the companies engaged in the Scottish oil industry, the year of formation, and the amount of paid-up capital and debentures, as at 1891.

Name.	Year about).		Capital paid up Debentures
Young's Paraffin Co.	1854	...	£658,771
Stanrigg Oil Co.	1865	...	50,000
Oakbank Oil Co.	1868	...	67,500
*Dalmeny Oil Co.	1871	...	18,900
Broxburn Oil Co.	1877	...	299,750
Burntisland Oil Co.	1881	...	244,950
Clippens Oil Co.	1882	...	397.235
West Lowthian Oil Co.	1883	...	81,748
Pumpherston Oil Co.	1883	...	197,010
*Holmes Oil Co.	1884	...	40,000
Linlithgow Oil Co.	1884	...	192,488
Hermand Oil Co.	1885	...	289,560
*James Ross & Co	1885	...	75 000
Caledonian Mineral Oil Co.†	1889	...	74.750
			£2,687 662

The production of mineral oils and paraffin, by the distillation of lignite, is carried on to a considerable extent in Saxony.

Two companies have been engaged in the manufacture of mineral oil from shale in New South Wales. The older, which has been in existence about twenty years, was formerly called the Western Kerosene Oil Company, but now goes by the name of the New South Wales Shale and Oil Company. The shale-field worked by this company is situated at Hartley Vale, near the Blue Mountains, on the Western Line, and the refinery is at Botany Bay. The distilling capacity of this company's plant is 400 tons of shale per week. The other company, formed ten or twelve or years ago, is termed the Australian Kerosene Shale and Oil Company. The mineral worked by this company is found at Joadja Creek, near Mitteagong, about eighty miles south of Sydney. The company distils about 200 tons of shale per week.

Mr. Griffin, in a report on the kerosene trade of New South Wales, gives the following tabular statement of the quantity of shale produced in the colony for each year from 1865 to 1884 inclusive.

* Manufactures crude oil, but does not refine.

† This Company purchased the business of the Lanark Oil Co.

	Tons.		Tons.
1865	570	1875	6,197
1866	2.770	1876	15,998
1867	4,079	1877	18,963
1868	16,952	1878	24,371
1869	7,500	1879	32,519
1870	8,580	1880	19,201
1871	14,700	1881	27,894
1872	11,040	1882	48,065
1873	17,850	1883	49,250
1874	12,100	1884	31.618

The shales employed for the manfacture of mineral oils in Scotland are generally associated with marls, limestones, and sandstones. They are usually of a brown or grey colour, the richer being of a soft nature, and the poorer hard and slate-like. The principal seams are known as the Fells, the Broxburn, and the Dunnet.

There are marked differences in the quality of the various Scottish shales in respect to the yield of crude oil and sulphate of ammonia, as well as in regard to the percentage of the various commercial products obtainable from the crude oil. The richer shales yield about 30 gallons of crude oil per ton of shale, while the inferior qualities give about 8 gallons less of oil, but a considerably larger amount of sulphate of ammonia.

Professor Liversidge, of the Sydney University, does not think that the name of "kerosene shale" is a proper one for the New South Wales mineral, for the reason that the substance does not possess the properties of a shale, and more nearly resembles cannel coal and torbanite.

The lignite distilled in Prussian Saxony is a particular variety of earthy lignite, occurring within a small portion of the Saxon Thuringian brown-coal formation between Weissenfels and Zeitz.

A laminated variety of shale, known as paper shale, which yields a large percentage of oil, is found in Servia and elsewhere. True shales when heated to redness in a closed vessel do not cake, so that the soft and black residue, after all the volatile matter has been driven off, retains the original form of the material. The proportion of mineral matter in the shale is usually about 73 per cent., but is occasionally as much as 80 per cent. The Broxburn shale yields:

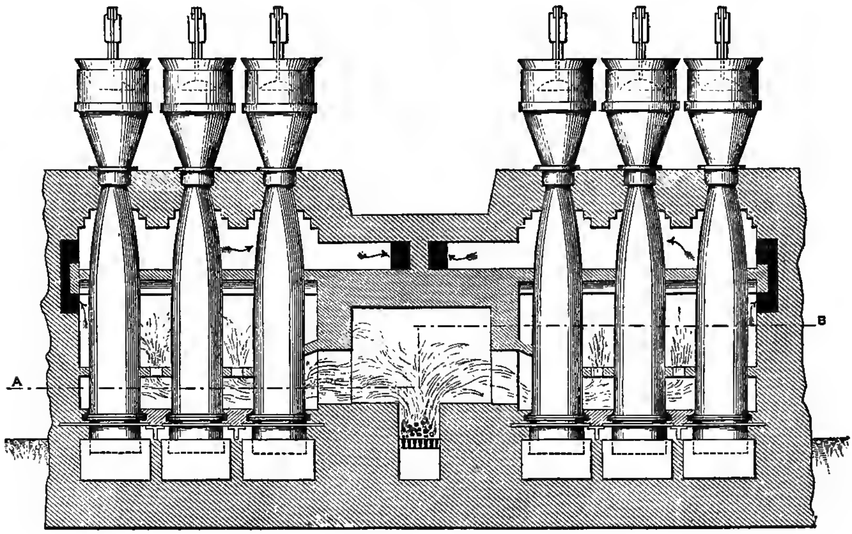
	Per cent.
Crude oil	12.5*
Water	8.5
Gas	3.0
Ash	67.0
Carbon in spent shale	9.0
	100.0

During the infancy of the Scottish shale-oil industry two methods of distillation were adopted—one intermittent, the other continuous. In the former system, which was that first employed, the shale, previously reduced to small fragments, was heated in horizontal cast-iron retorts, similar to those employed in coal-gas manufacture, the retorts being discharged and recharged when the whole of the volatile matters had been driven off. The continuous system was conducted in cylindrical or oval retorts of cast-iron, about two feet in diameter, and eight or ten feet in length, six or eight of which were set vertically in a furnace, Figs. 121, 122, 123. In these retorts the shale, previously broken by machinery, was exposed to a dull red heat for a period ranging from twelve to twenty hours, a jet of steam being introduced at the bottom of the retort, and the products conducted from

* The yield of crude oil may be stated to range from 22 to 30, or in some cases even 40 gallons per ton of shale, but where the yield exceeds 30 gallons, the oil is usually inferior in respect to the percentage of solid paraffin and quality of the heavy oils.

the top. The furnace was so constructed that the lower part of the retort received the greatest heat, and from time to time a portion of the exhausted shale was removed from the bottom of the retort, which was sealed with

FIG. 121.

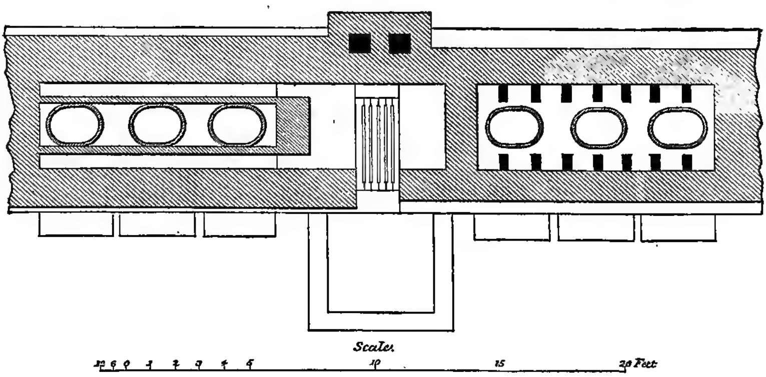


Distillation of Shale. Sectional Elevation.

water, a corresponding quantity of fresh shale being introduced through the hopper at the top.

The modern representatives of the intermittent and continuous methods of distillation are the Henderson system and the Young and Beilby system

FIG. 122.

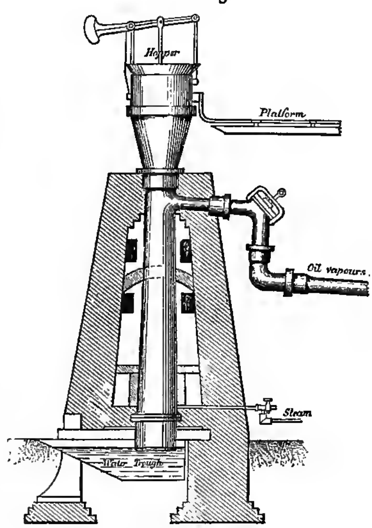


Sectional Plan on A B.

respectively. The Henderson system is characterised by the provision of an arrangement for utilising as fuel the carbon remaining in the spent shale, which sometimes amounts to as much as 12 or 14 per cent. The retorts used, Fig. 124 (p. 218), are about fifteen feet in length and take a charge of eighteen hundredweight of shale. They are arranged vertically in a series of four in a furnace-chamber or oven. The oven is a high-arched chamber, constructed

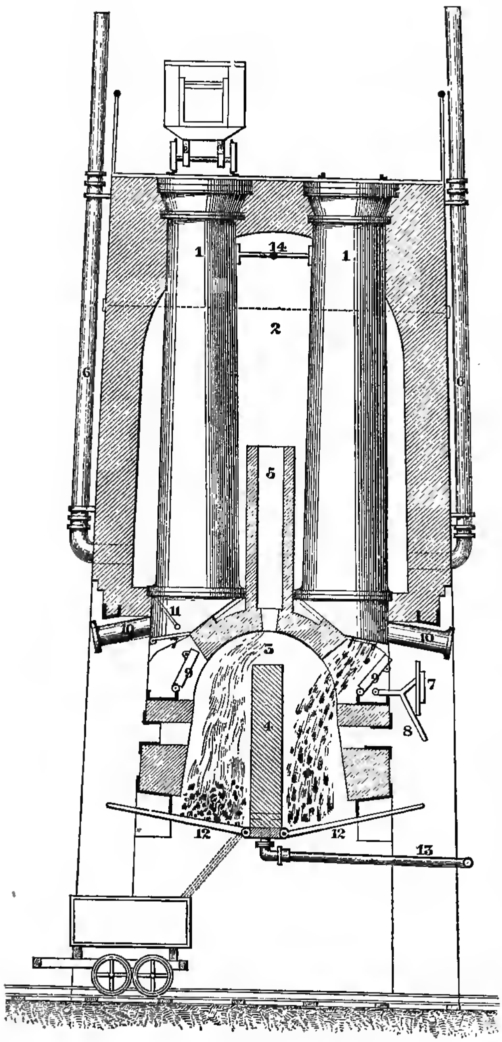
of brickwork, and there is formed beneath it a large fire-chamber or fuel space, divided in two by a partition wall. The fire-chamber is surmounted by an arched roof, along the centre of which, apertures are formed for the passage of the fire gases into the oven space above. The fire gases are led at first towards the upper part of the oven by vertical flue walls or screens, and they finally pass off from the oven by flues leading from the outer bottom parts into the main flues communicating with the chimney. The bottom of each retort is formed with its inner side bevelled, and it is built into and projects down through the sole or floor of the oven. The discharge opening of the retort formed at the extreme bottom end, and the cover, are slightly inclined from the horizontal, the lower end being outermost, so that the oil falling on the cover may run down it towards the oil outlet. The retort bottom is situated in a casement or space made with an iron framing fixed in the brickwork, and with its inner side opening into the fire-chamber, whilst it is also open on the outer side. In the casement, there is an incline valve made of iron lined with fire-clay, and arranged to turn on journals at its bottom corners. This valve serves to separate the bottom of the retort from the fire-chamber, and thus prevents the fire from injuring the bottom cover or door of the retort and its fittings. When, however, the cover is removed, the valve can be turned over so as to form an inclined plane or shoot to guide down the spent shale from the retort into the fire-chamber. A light, malleable-iron, portable hand-lever, with a horizontal spindle, is made to turn in bearings formed in the bottom of the casement, so as to remove the door away from the retort, or so as to lift it into position. In the upper part of the casement frame, in each side, there is a wedge recess, into which wedges are driven to fix the door tightly when in position, these wedges being taken out prior to its removal. In the bottom of the retort is a hinged grating which keeps the shale from the cold or outer corner when distilling, and when the door is removed prevents the spent shale from falling down until the valve is turned over outwards to guide it down into the fire-chamber. At the bottom of the fire-chamber, there are two large opening doors, one being on each side of the partition wall, for the easy removal of the final ashes, or exhausted material, into hutches below. A series of pipes is arranged along one side of the oven. Steam is passed through these pipes, and superheated to the temperature of the oven (about 426° C. or 800° F.), from which it passes by branches into the tops of the retorts, and travels downwards, diffusing the proper heat uniformly through the mass of shale, and sweeping the oil vapours out of the region of the heat as soon as they are formed, the oil vapours being conveyed from the bottom of the retort by a pipe leading to the condensers. The following is the method of working the set of four retorts:—Having first got up a suitable heat in the oven by means of ordinary fuel, one retort is charged from the top with shale. Four hours later, a second retort, diagonally opposite to the first, is charged. At the eighth hour from the start, a third retort is charged—namely, the one on

FIG. 123.



Vertical Section.

FIG. 124.



1. Retorts—flat oval in cross section.
2. Oven—arched chamber containing four retorts.
3. Furnace.
4. Dividing wall in furnace.
5. Flue—acting as a screen for bottom of retort.
6. Exit pipes from oven for heated gases.
7. Movable door for bottom of retort.
8. Implement for removal of door.
9. Valve forming a shoot which folds back into recess in furnace arch.
10. Outlet pipe for oil vapours.
11. Grating which prevents shale from falling into corner removed from heat, and protects oil outlet.
12. Bottom plate of furnace which folds down, the cinder being precipitated into bogey.
13. Inlet for gas consumed as fuel.
14. Steam-pipes.

the same side of the partition wall as the first, and at the twelfth hour the fourth is charged. The heat is maintained with ordinary fuel until the sixteenth hour, when the material in the first retort will be exhausted so far as the distillation is concerned, and it can be discharged into the fire-chamber to be used as fuel, and the retort again charged. Thereafter, at each period of four hours, the retorts are discharged and recharged in the order in which they were first charged. The spent shale falls into the furnace black although hot, but in a few minutes it is glowing brightly. The furnace and oven are constructed so as to cause a very gentle influx of air, as the spent shale contains but little carbon, and the fire would be extinguished by a strong draught. The slow current enables the retorts to get the full benefit of the heat. The heating of the retorts is aided by the combustion in the furnace of the incondensable gaseous products of distillation, and, occasionally, as in cold weather, by the addition to the spent shale of a little coal. The principal advantages claimed for the system as compared with the old vertical retort, are:—

Economy in labour, skilled labour and great attention not being required; saving in fuel; diminution in cost of maintenance, and extension of life of retorts, in consequence of the mild and equable temperature ensured; certainty and

regularity of working; improvement in yield and quality of products from the crude oil.

In the continuous system of Messrs. William Young and George Beilby the retort employed (now known as the Pentland retort) is composite, the upper part being made of iron, and the lower of fire-brick, Figs. 125 and 126.

The retorts are set in groups of four, and each group is surmounted with a quadruple hopper containing as much shale as the retorts themselves. At the lower end, each retort is closed by a faced mouth-piece and steel door, and there is a provision for the introduction of steam. The heating of the

FIG. 125.

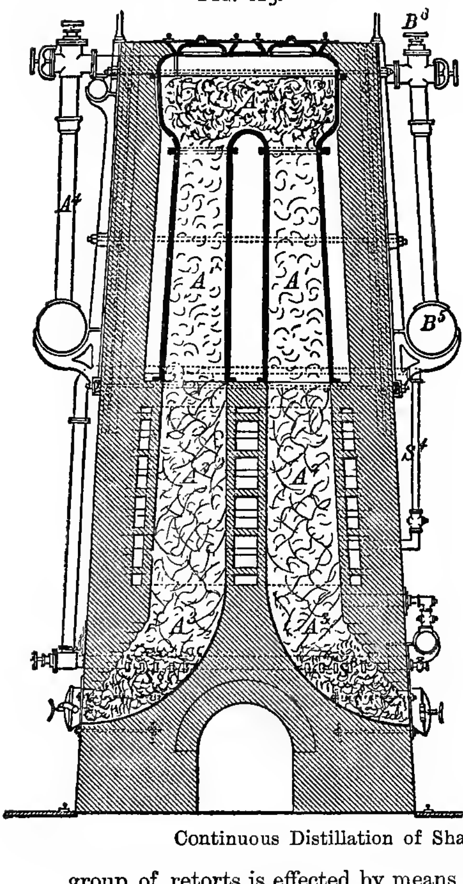
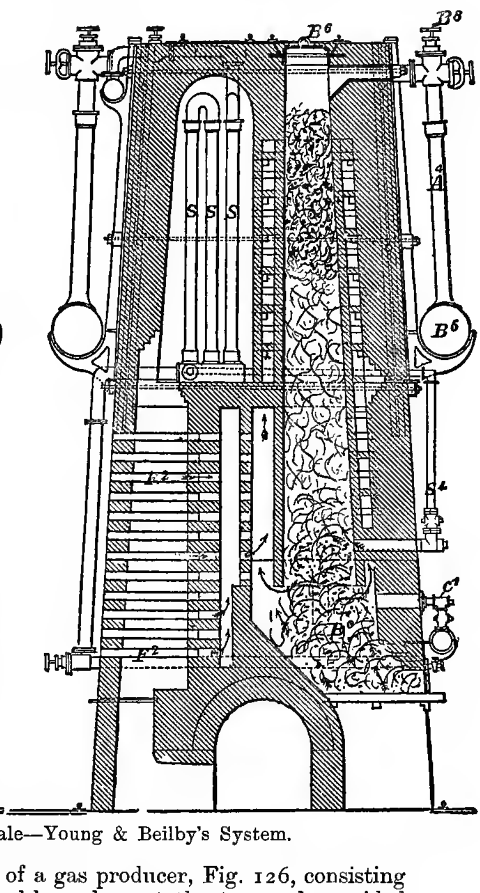


FIG. 126.



Continuous Distillation of Shale—Young & Beilby's System.

group of retorts is effected by means of a gas producer, Fig. 126, consisting of a vertical retort built of brick, closed by a door at the top, and provided with an exit-pipe communicating with a system of mains and condensers. At its lower end, the retort terminates in a closed fire-place and ash-pit, with regulating doors and dampers. The dross or small coal is introduced by the top door, and resting on the fire-bars, fills the retort from top to bottom. The upper part of the retort, being surrounded by flues through which the fire-gases are led, is kept at a full red heat. The coal at this part of the retort is distilled, and parts with gases and vapours which pass away by the exit-pipe to be cooled and condensed. As the coke passes down in the retort it is met by a current of steam, which is partially decomposed, with

the production of ammonia and water-gas, which pass off with the other volatile products. When such coke as has escaped the action of the steam reaches the fire-bars, it is burned into carbonic oxide by a regulated admission of air. The carbonic oxide passes off by ports at the lower end of the retort, and is burned in the flues surrounding the shale retorts. The gases from the upper part of the retort, after having been deprived of their condensable constituents, are also returned into, and burned in, the setting of the retorts. It is claimed that by this system of firing, less fuel is used than by the open furnace, and that the ammonia and tar recovered from the coal more than pay its first cost.

When commencing work with the Young and Beilby retort, the lower portion, having been raised to the proper temperature, is filled with spent shale up to the junction of the upper iron portion. Broken shale is then introduced until the retort is full to the hopper, which is closed by a bell valve. Steam is then let into the lower end of the retort, and passing through the red-hot material, is highly superheated, and rapidly conveys heat to the raw shale in the upper retort, which is further heated by the flue gases passing outside. The oil vapours and steam passing off by the exit-pipe are cooled and condensed. The shale at the lower end of the iron retort, receiving the first effect of the highly-heated steam, is first exhausted of its hydrocarbons, and the downward movement of the whole column within the retort having been effected by the withdrawal of a portion of the spent shale, the material passes from the lower end of the iron retort into the more highly heated fire-brick retort below, where in the presence of steam a large part of its nitrogen is converted into ammonia, which passes away with the oil vapours and steam. As the column of shale is moved downwards by successive withdrawals from below, fresh material is introduced through the hopper at the top, and the operation is so regulated that no shale containing oil is allowed to pass into the highly-heated lower retort.

By this method of distillation, it is claimed that a larger quantity of paraffin is obtained from the crude oil, and the increased yield of sulphate of ammonia, as compared with that obtained with any other retort in use, is stated to be no less than from 14 to 25 lbs. per ton of shale.

The vapours evolved from the shale are condensed by being passed through a series of 70 to 100 vertical 4-inch pipes for each bench of 52 retorts, the lower ends of which are fitted into a chest. The condensed products are ammoniacal liquor and crude oil. From the uncondensed products, gasoline is obtained by subjecting them to cold and pressure, or by passing them through a coke tower charged with heavy oil, the very volatile hydrocarbons dissolved by the oil being recovered by distillation. The former process, which was designed by the late Mr. J. J. Coleman, consists in compressing the gas as it issues from the condensers to 100 or 120 lbs. per square inch, by means of two double-acting pumps, and forcing it through three tubular condensers, the first two of which are cooled by the circulation of water, while the third is cooled to 40° or 50° below zero by the expansion of the gas which remains uncondensed. The compression system yields a larger percentage of hydrocarbons than the coke-tower system, but the latter is preferred as being far less costly to work. The liquid obtained has a specific gravity of .700 to .715, and on rectification furnishes gasoline and light naphtha. The uncondensed gas is employed as fuel.

From the ammoniacal liquor, ammonia is obtained by distillation, the gas being conducted from the stills into "cracker boxes," or saturators, lined with lead (commonly 4 feet in length, 3 feet in width and 2 feet in depth), and discharged through perforated lead pipes into sulphuric acid (50° Twaddell). The sulphate of ammonia solution thus formed having been allowed to settle.

is then transferred to another vessel, where it is evaporated, and the crystallised salt is "fished out" drained and dried. The yield of sulphate of ammonia ranges within the wide limits of 10 and 60 pounds per ton of shale, according to the class of shale and the system adopted in its distillation, but averages about 25 pounds per ton.

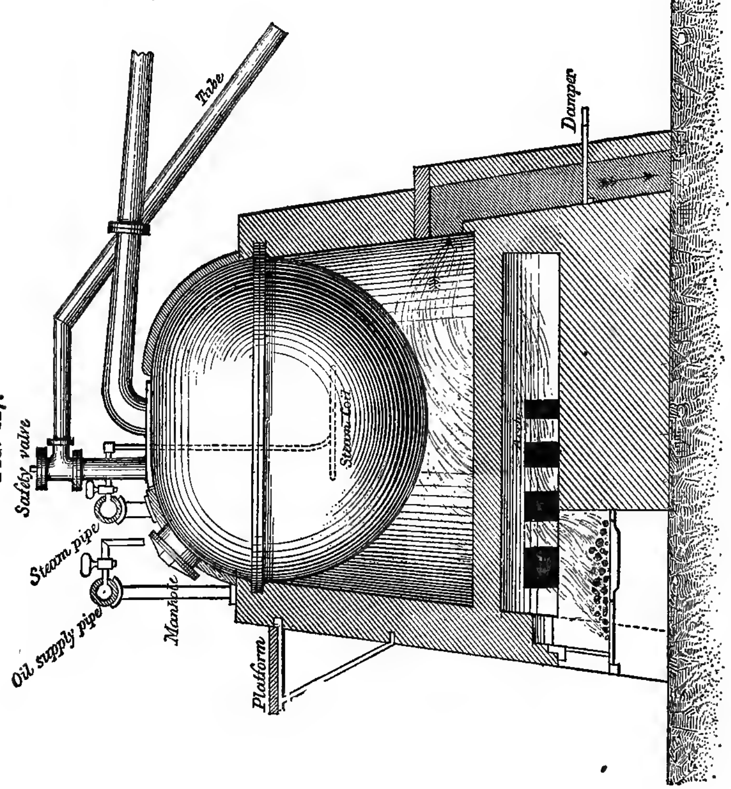
For the distillation of the ammoniacal liquor, column stills, in which the liquor admitted at the top comes into contact with steam blown in at the bottom, have been found a great improvement on the ordinary boiler stills. The column still patented by Mr. Beilby is provided with a series of saucer-shaped plates, each alternate plate being inverted, and all so perforated that the liquor trickles to the centre of the one saucer, and falling on its inverted neighbour below, runs to its outer edge, and so passes from the centre of one to the rim of the other until it reaches the bottom of the still, the liquor being thus brought thoroughly into contact with the steam, and the ammonia being completely volatilised. Mr. Henderson has devised an improved form of column still, with the object of diminishing the considerable quantity of steam employed in the ordinary column still. The liquor is admitted in the Henderson still into an annular tray or dish, round which it flows, and from which it falls into a second and thence into a third annular tray, flowing round each. It then falls on to the first of a series of diaphragms, consisting of an annular outer channel, and a central dish connected with each other so that the liquor may flow round the channel and into the dish, and *vice versâ*. The channel and dish are connected with each other by a saddle-shaped cover, the edges of which rest on the bottom of the channel and dish respectively, but these edges are scalloped or notched throughout their whole length. The liquor in the tray and dish rises to a height of about half an inch above these notches. As the liquor follows its course from channel to dish, and dish to channel, through the series of diaphragms, the steam, under pressure, is rushing under the saddle-shaped cover, through the notches, and forcing its way at every point into and through the circulating liquor, thus completely removing the ammonia. At the same time the violent agitation kept up throughout the whole course of the liquid prevents to a large extent the formation of a deposit. It is claimed that while under the older system only about 3000 to 4000 gallons of liquor could be distilled per still per day, no less than 45,000 to 50,000 gallons of liquor can be passed through a Henderson still per day, and three steam-boilers will suffice for work which formerly required six similar boilers.

Crude shale oil is of a dark green colour, and has a specific gravity of .865, and upwards. The first step in the process of refining consists in the distillation of the oil to dryness, in cast-iron pot-shaped stills, Fig. 127 (p. 222), into which steam, often superheated, is passed. The condensing arrangement consists of a series of pipes, extending, with a slight fall, through a tank of water. Fig. 128 represents a cylindrical condenser. The distilled oil having been "washed" with sulphuric acid, and afterwards with caustic soda solution, is then subjected to fractional distillation in cylindrical boiler-plate stills, Fig. 129, having a capacity of 4000 to 5000 gallons. Steam is introduced into the still after the more volatile constituents have passed off. The first product obtained is crude naphtha, and at a higher temperature the burning-oil distillate issues from the condenser, and is collected separately. The heavy oil which distils at a still higher temperature yields lubricating oils and paraffin.

The shale oil yields in addition acid and basic substances.

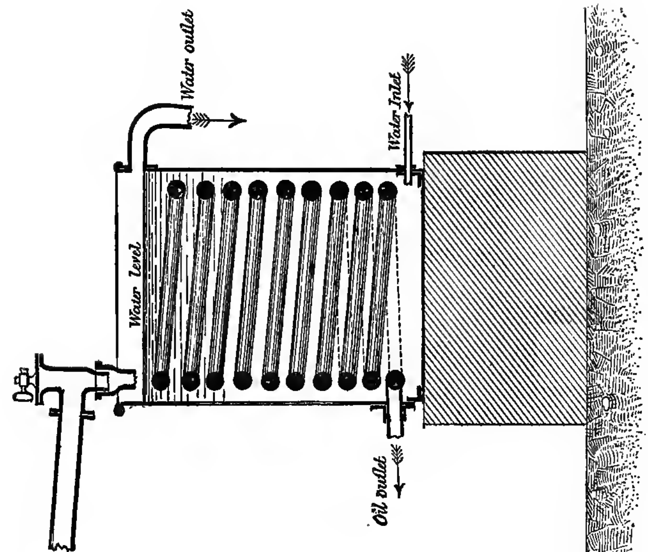
An apparatus for the continuous distillation of crude shale oil, as it comes from the retorts, was patented by Mr. N. M. Henderson, in 1885. The apparatus, represented in Figs. 130, 131, 132, and 133 (pp. 224–226), consists of a central primary waggon-shaped still, connected with two side stills

FIG. 127.



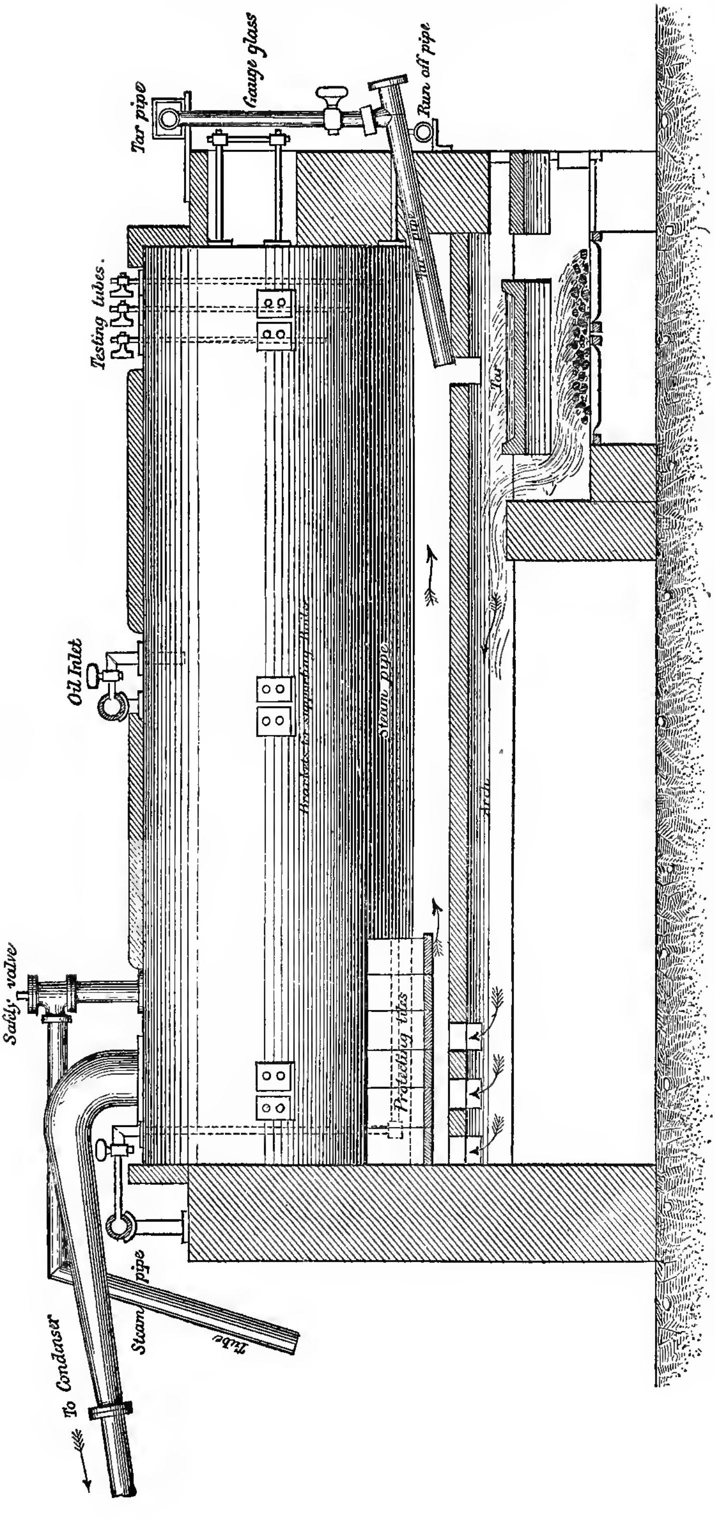
CAST IRON STILL. CAPACITY 1300 GALLONS.

FIG. 128.



ROUND CONDENSER TANK. SECTION.

FIG. 129.



OIL BOILER STILL. CAPACITY 4,000 GALLONS.

FIG. 130.

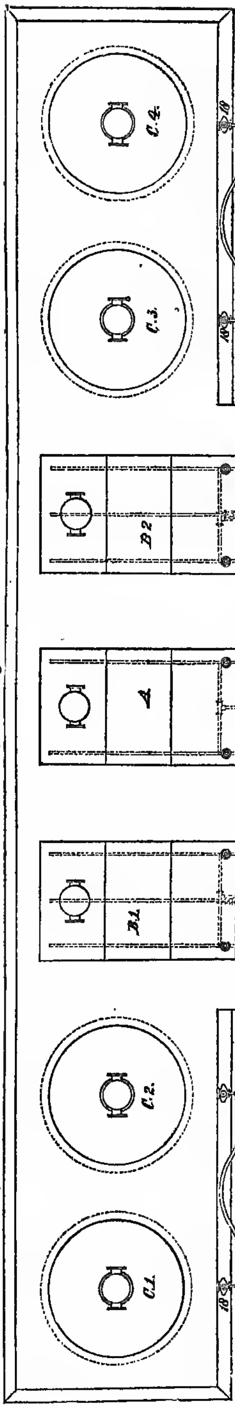
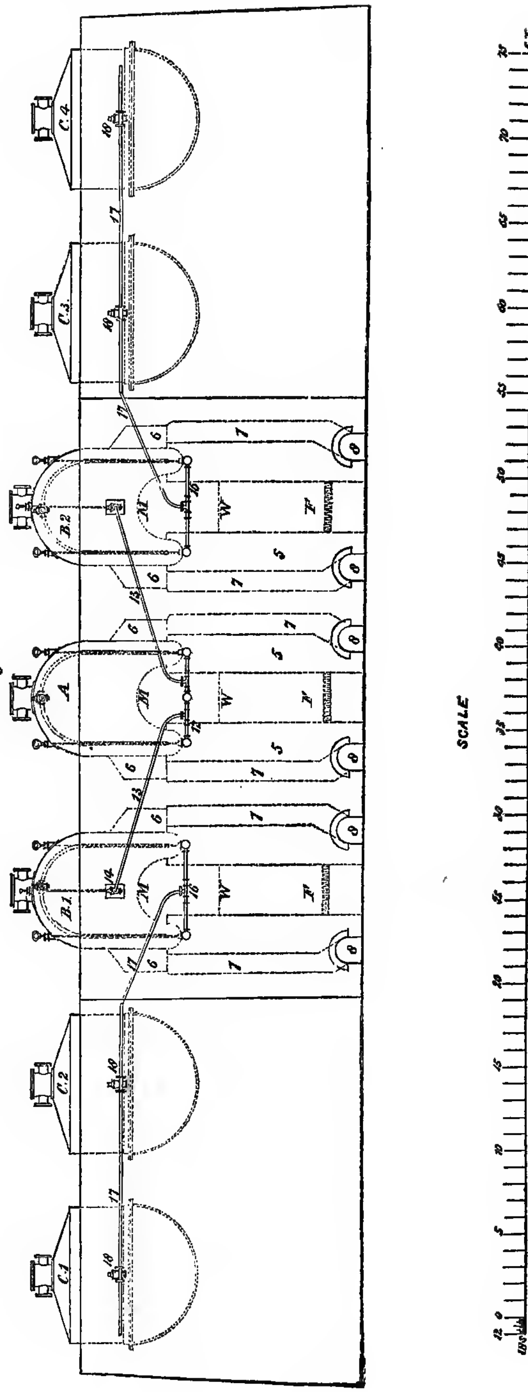


FIG. 131.



Henderson's Crude Oil Stills. Continuous System.

DESCRIPTION OF FIGURES.

Fig. 130 is a plan and Fig. 131 a front elevation of a set of oil stills, comprising a central primary still *A*, with two secondary stills, B^1, B^2, and four coking stills, C^1, C^2, C^3, C^4, Figs. 132 and 133 are an enlarged sectional plan and an enlarged sectional front elevation, showing the primary still *A*, and one, B^1, of the secondary stills. The same reference letters and numerals apply to the whole of the figures.

D. Deeper lateral parts of stills, protected from direct fire-heat by being built into walls, 5.

F. Fire-grate, placed low so as to form combustion chamber between it and the concave bottom *M*, of the still.

W. Fire bridge. 6, 7, 8, Flues.

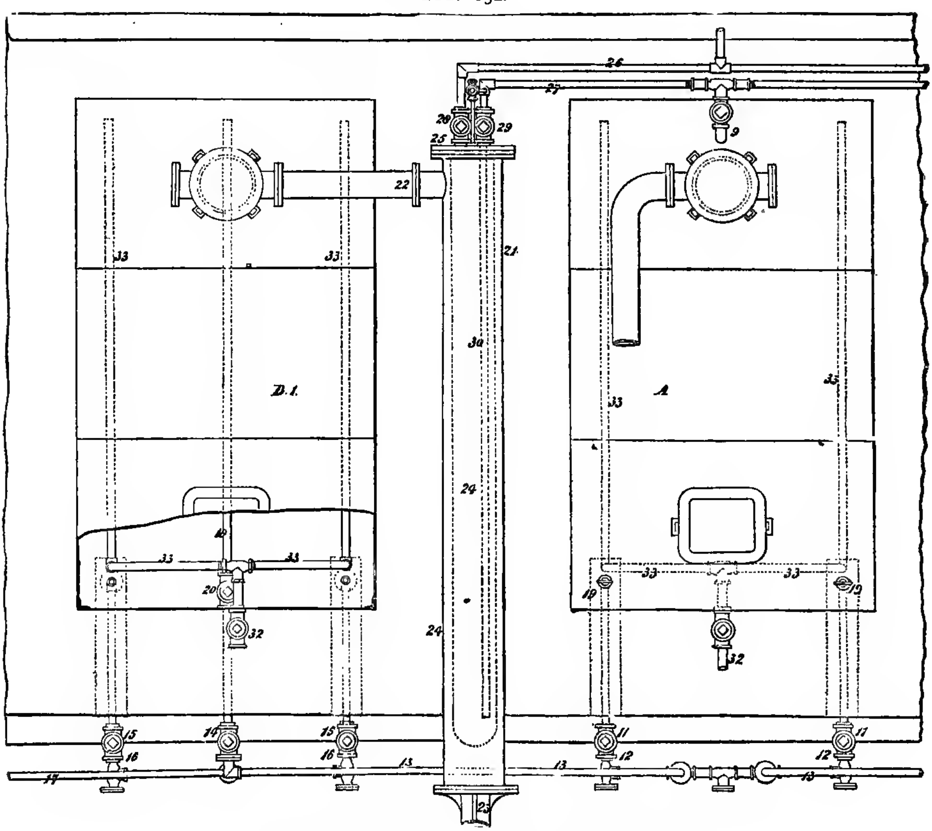
9. Vertical feed-pipe to still *A*. 10. Feed-pipes to stills B^1, B^2. 11. Outlet valves from deeper parts of still *A*, communicating with external piping, 12. 13. Branches to feed-pipes, 10. 14. Valves on feed-pipes, 10. 15. Outlet valves from stills B^1, B^2. 16. External piping. 17. Branch pipes. 18. Stop-valves—all connected with stills B^1, B^2. 19. Rods, passing through stuffing-boxes, connected with safety stop-plugs inside retorts, at the outlets. 20. Internal valves in connection with feed inlets.

21. (Figs. 132 and 133) outer cylinder of feed-heater. 22. Pipe conveying vapours from still B^1. 23. Pipe conveying vapours to condensers. 24. Inner cylinder of feed-heater.

25. End cover of feed-heater. 26, 27. Pipes for entrance and egress of oil to be heated. 28, 29. Stop-cocks. 30. Egress pipes. 31. Stop-valve for letting off separated vapour, air or gas.

32. Branch pipes from main steam-pipe (not shown) for injecting steam in stills, *A*, B^1 and B^2. 33. Perforated branches of steam-pipes.

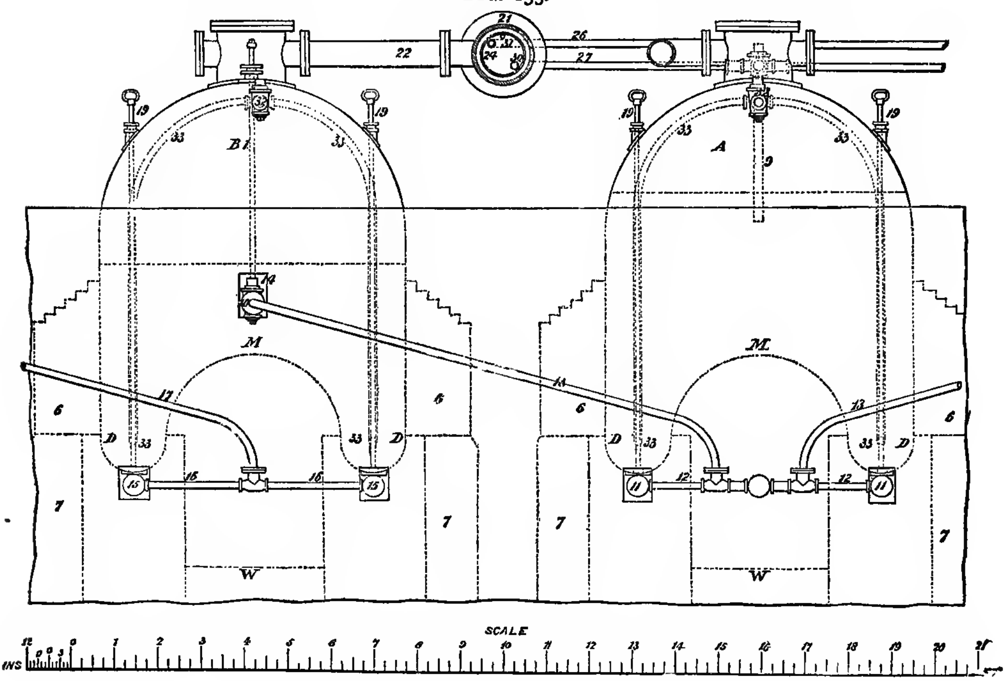
FIG. 132.



Henderson's Crude Oil Stills. Continuous System.

one on each side, beyond which there is, on each side, a set of two or more pot-shaped coking stills, connected by pipes with the side stills. The crude oil, previously heated by passing through feed heaters, in which the heat of the vapour passing out of the still is utilised, passes into the central still, where it is kept boiling at the low regulated temperature required for distilling off the most volatile fraction. From the back of the still, the increasingly heavy portion of its contents is continuously being drawn off into the side stills, where at a higher temperature a heavier portion is being drawn off. From the front of these stills, in a similar manner, the increasingly dense oil passes continuously off into one of the coking stills, in which the material is distilled to dryness. The feed-pipe in the primary still dips just below the surface of the oil, whilst in each secondary still the oil enters by a

FIG. 133.



Henderson's Crude Oil Stills. Continuous System.

horizontal pipe, situated at a short distance above the concavity of the waggon-shaped still bottom, the feed-pipe entering at one end of the still and delivering the oil near the other end. As the volatile part of the oil is distilled off, the remaining oil, becoming heavier, descends to the deep sides of the bottom of the still, whence it passes by an outlet pipe in the case of the primary still to the secondary stills, and in the case of the secondary stills to the coking stills. Thus, without further attention than starting the stills, keeping up the heat, and changing the current from one coking still to another when required, the work of distillation may be said to go on automatically, the oil in the central and two side stills remaining constant in density, and giving off distillates of homogeneous quality. There is thus obtained from the crude oil a set of three fractions, and it is claimed that the work which formerly required 32 separate stills is now effected by nine connected stills, namely, the three continuous stills and six coking stills,

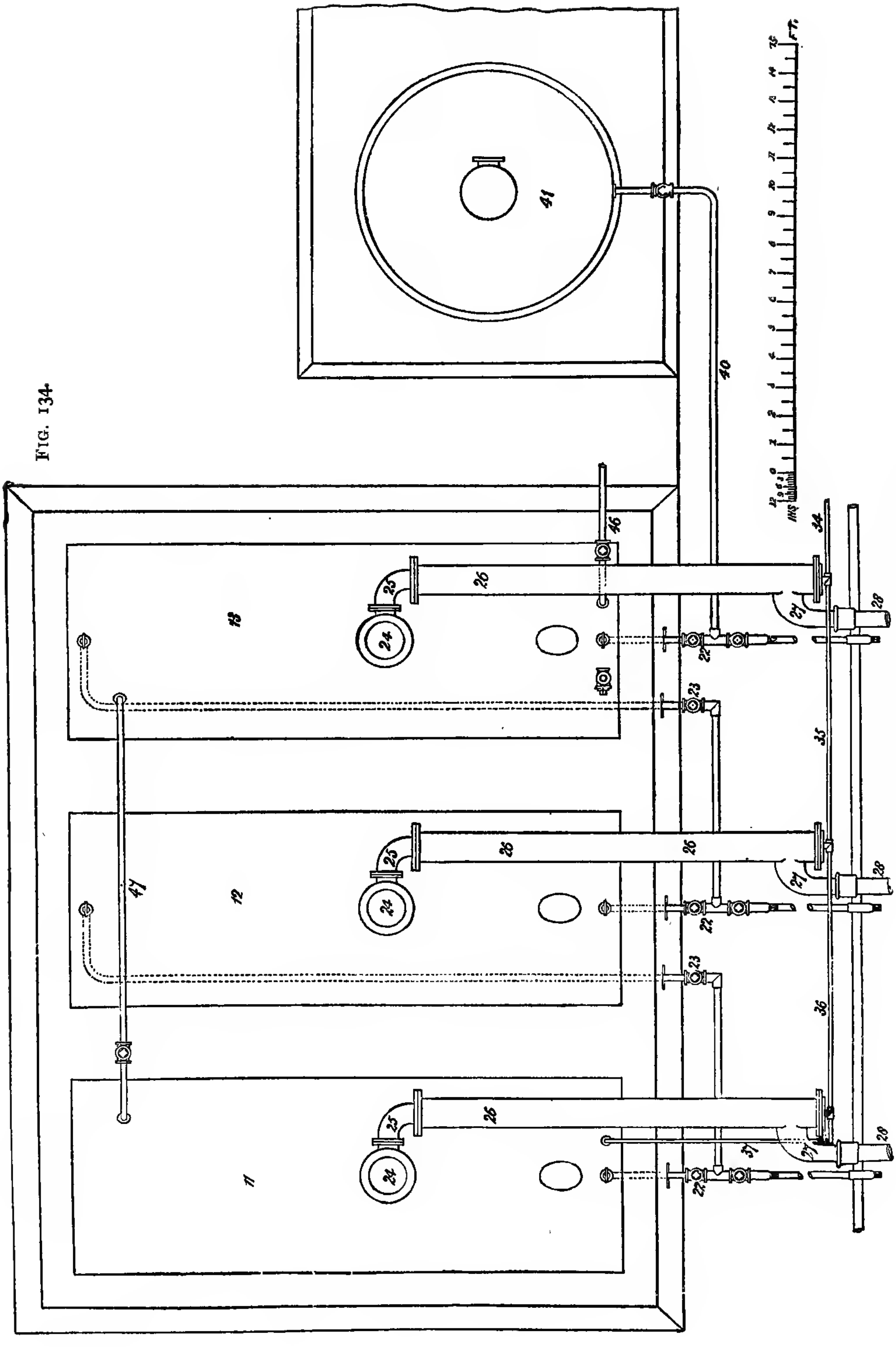
two only of the latter being kept at work at the same time, the others being for interchange.

Two years previously, Mr. Henderson patented an arrangement for the continuous distillation of "once run" oil, or crude oil after one distillation, in the ordinary pot stills, consisting of three connected horizontal cylindrical stills, Figs. 134, 135, 136, 137, 138 and 139 (pp. 228–232), which may be seven feet in diameter by nineteen feet in length. Each still is fitted with an outlet or discharge pipe in the bottom at one end, and an inlet pipe enters the same end of each still at a higher level, but is continued inside the still to the other end, so that the actual inlet may be as far as possible from the outlet. Each still is formed with the usual dome or vapour chest into which the volatilised oil rises, and from which it passes by a curved branch into a long horizontal cylinder or pipe wherein its heat is utilised in raising the temperature of the oil which is being continuously fed into the first of the three stills. In the third still, where there is a tendency for coke or adhesive carbonaceous matter to separate from the oil, there are fitted, inside the still, plates or dishes to promote the circulation of the oil, and to form receptacles for the coke, so that it may not adhere to the bottom of the still. These dishes or circulating plates extend along the still on each side of its longitudinal central plane, with a middle space between them. Their bottoms are shaped so as to be nearly parallel to or concentric with the bottom shell of the still, and they are hinged to straps which are riveted to the sides of the still, their inner parts being supported by feet resting on the bottom of the still; while provision is made for attaching chains by means of which the dishes can be turned up for cleaning purposes. The oil circulates so as to pass from the middle under the dishes or plates and up the sides of the stills, returning downwards from the sides towards the middle; and this circulation is assisted and ensured by jets of steam issuing from perforations in the sides of a pipe extending along the still near the middle of the bottom. Two or more residue stills are provided in connection with each set of three stills, in order that the process may not be interrupted when the residue still is being cleaned out. The principle of action of this distillatory arrangement is similar to that of the apparatus previously described. It is claimed that 285,000 gallons of oil may be put through a set of three stills thus worked continuously in twelve days, while not more than 126,000 gallons could be distilled in the same stills in the same period under the old system. There is also stated to be a considerable saving in labour, fuel and repairs.

In carrying out the process of the continuous distillation of shale oil, Messrs. Young and Beilby prefer to use a horizontal cylindrical still partitioned transversely in such a manner as to form a number of separate chambers through which the oil passes in its course from the inlet end of the still to the outlet end. Each partitioned space is provided with a vapour pipe leading to a condensing arrangement, and the furnace is so constructed that the compartments are heated to temperatures suitable for the volatilisation of the various products, the outlet end of the still being most highly heated and the temperature graduated by successive stages to a comparatively low heat at the inlet end. Fractional condensation forms a feature of the system.

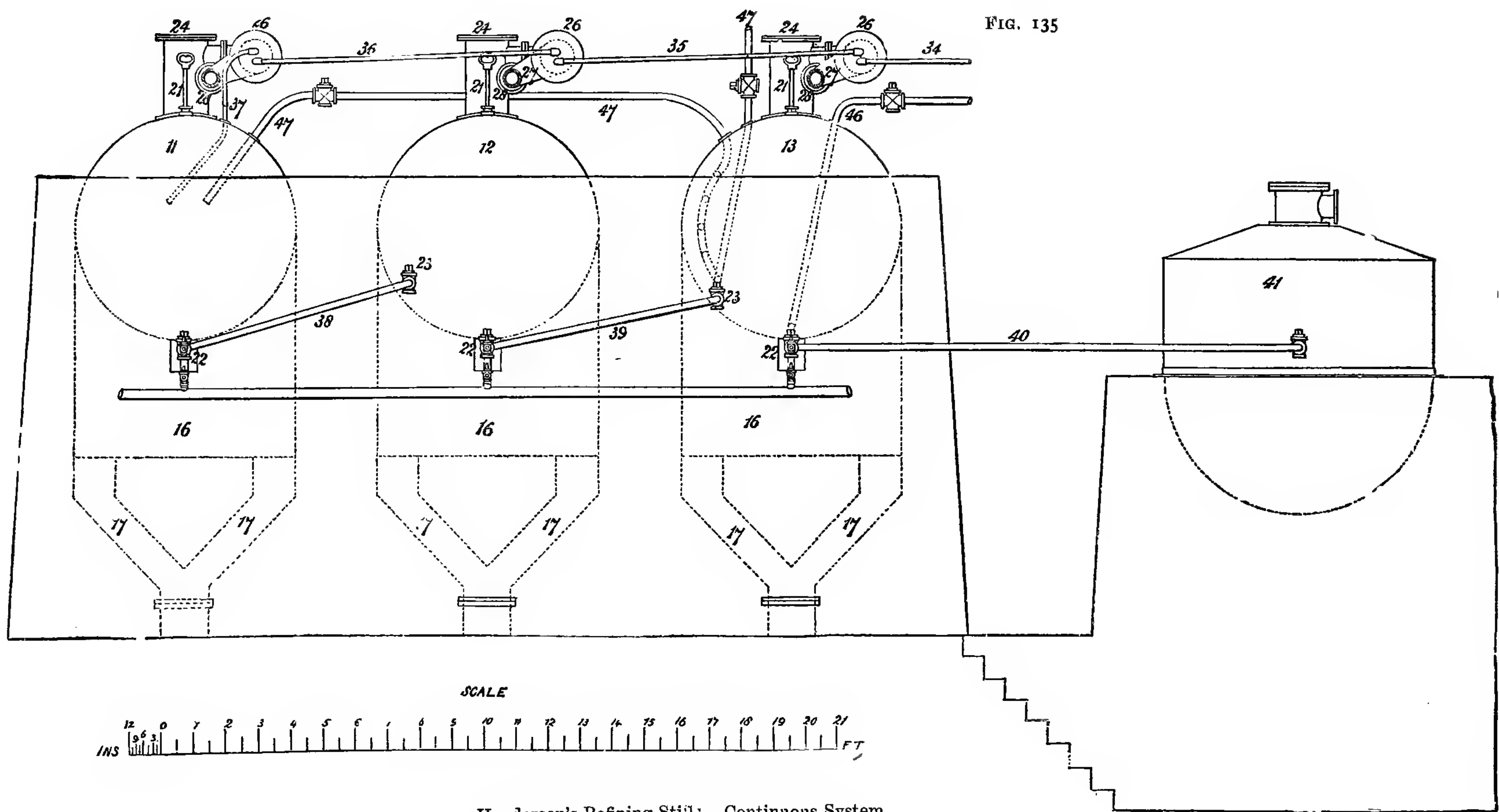
The burning-oil distillate is washed with acid and alkali, and undergoes a second fractional distillation, wherein an additional quantity of naphtha and heavy oil are separated. The burning-oil distillate after being subjected to a third chemical treatment is again distilled, the products being fractionated to suit the requirements of the manufacturer; in some cases the oils are finally washed with acid, alkali and water. The crude naphtha receives the same treatment with chemicals and is fractionated by distillation.

FIG. 134.



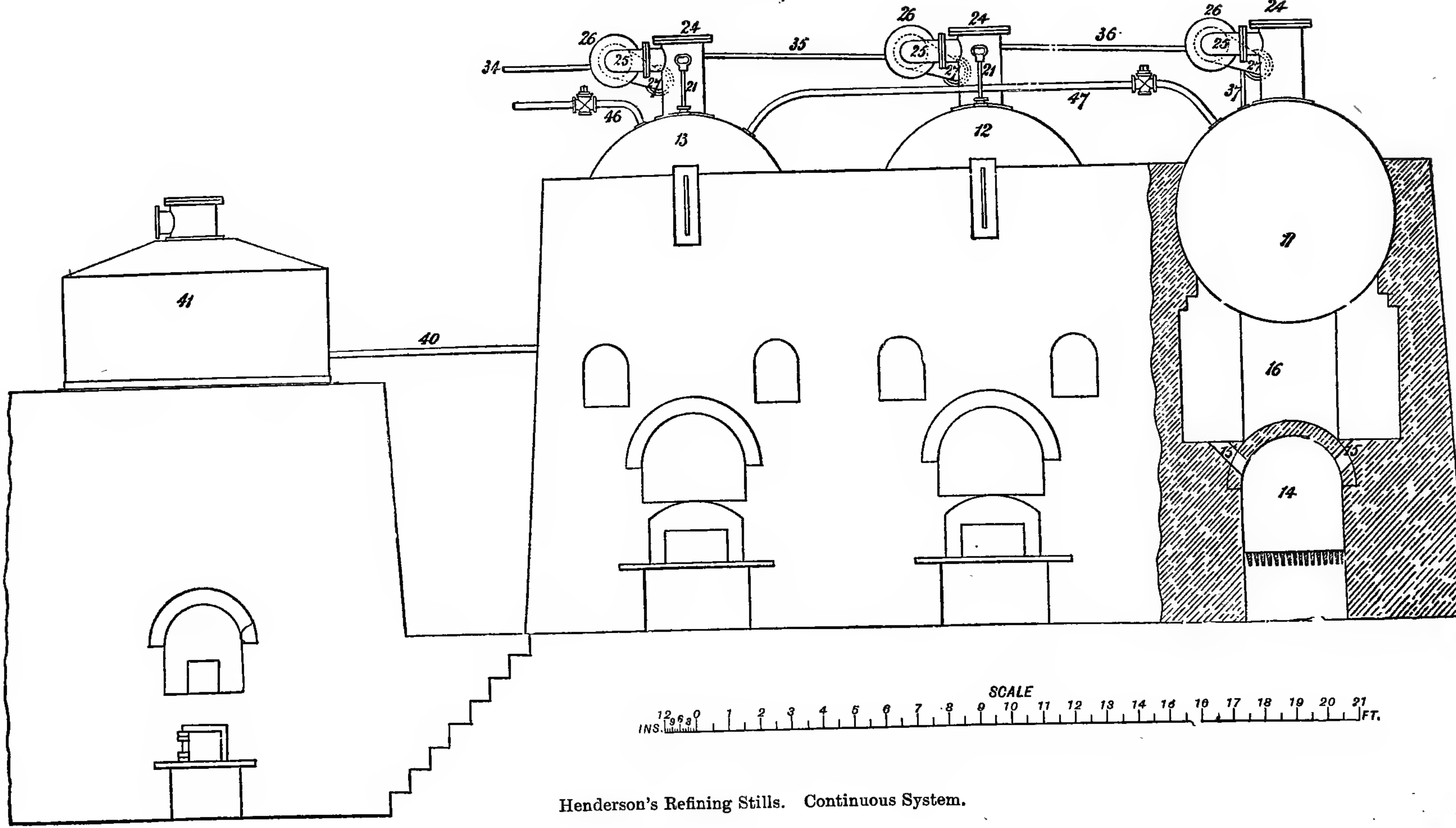
Henderson's Refining Stills. Continuous System.

FIG. 135



Henderson's Refining Stills. Continuous System.

FIG. 136.



Henderson's Refining Stills. Continuous System.

Fig. 137.

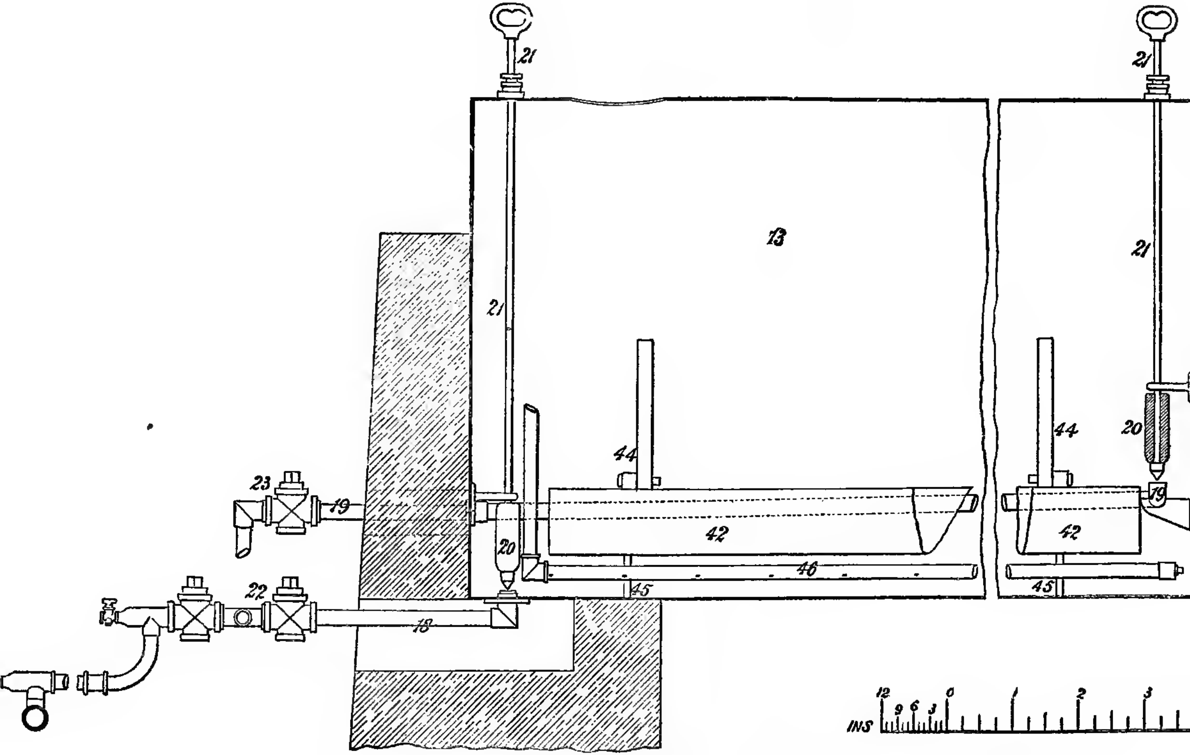
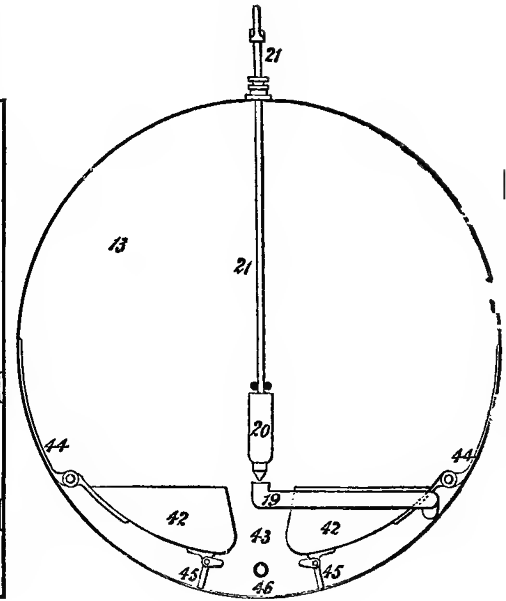


Fig. 138.

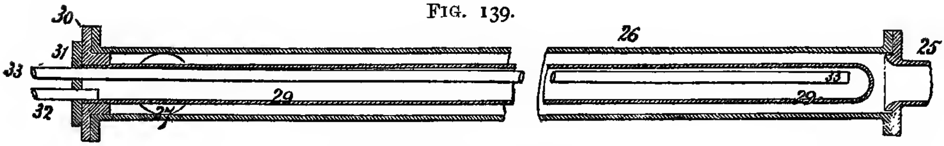


Henderson's Refining Stills. Continuous System

From the heavy oil obtained in the first fractional distillation, paraffin of comparatively high melting point separates at common temperatures, and a further quantity of paraffin is obtained by cooling the oil and pressing the semi-solid mass.

It was formerly the practice to separate the soft paraffin from the heavy oil obtained in the first fractional distillation, after the crystallisation of the hard paraffin, by bringing the oil into contact with the surface of a revolving cylinder, Figs. 140, 141 and 142, through which cooled calcium chloride solution was made to circulate, the paraffin adhering to the cold surface being continuously removed by a scraper. Another arrangement employed for the refrigeration of the oil consisted of a fixed cylindrical vessel, Fig. 143 (p. 235), holding about 200 gallons, jacketed so as to provide an annular space for the circulation of the cold brine. The oil, as it is cooled, adheres to the inner surface of the vessel, and is removed by a set of scrapers attached to a vertical shaft, the whole mass being thus reduced in temperature to the

FIG. 139.



DESCRIPTION OF FIGURES.

Fig. 134 is a plan, and Fig. 135 a back elevation of a set of three stills, with one of the residue stills. Fig. 136 is a front elevation, partly in section. Figs. 137 and 138 are enlarged longitudinal and transverse vertical sections of the third still, and Fig. 139 is an enlarged longitudinal section of one of the feed-heaters. The same numerals apply to the whole of the figures.

11, 12 and 13. Stills. 14. Furnaces. 15. Lateral openings for fire gases. 16. Heating chamber. 17. Lateral flues. 18. Discharge pipes from stills. 19. Inlet pipe to stills, 12 and 13. 20. Safety plug valves to inlet and outlet pipes. 21. Rods connected with the valves and passing through stuffing-boxes. 22, 23. External stop-cocks. 24. Domes of stills. 25. Curved branches from domes. 26. Horizontal vapour pipes, forming feed-heaters. 27. Outlets for vapour. 28. Vapour pipes to condensers. 29. Inner cylinders of feed-heaters with flanges, 30, and closing plates, 31. 32. Inlet pipes for feed oil. 33. Outlet pipes for feed oil. 34. 35, and 36 Pipes conveying heated oil to stills. 37. Delivery pipe from still 11. 38. Delivery pipe from still 11 to still 12. 39. Delivery pipe from still 12 to still 13. 40. Delivery pipe from still 13 to residue still 41. 42. Dishes or plates (usually applied to the third still) for promoting circulation and for collecting coke. 43. Space between the dishes. 44. Straps or hinges of dishes. 45. Feet of dishes. 46. Perforated steam-pipe. 47. Pipe which may be used as a feed-heater.

required extent. It has, however, been found that the expression of the oil is more readily effected if the paraffin is caused to assume a more distinctly crystalline form by the slow cooling of the oil in considerable bulk, and various arrangements for effecting this object have been patented by Mr. Henderson, Mr. Beilby, and others.

Mr. Henderson's apparatus, Figs. 144, 145, 146 and 147 (pp. 236–238), consists of a jacketed trough with a circular bottom, across which trough, at short distances from each other, discs are placed, dividing the trough into a series of narrow partitions. The discs themselves consist of two thin plates bolted together, but having a space left between them, and in that space, as well as in the jacket surrounding the trough, a circulation of cooled brine is kept up. The lubricating oil distillate being supplied to the trough, a crop of paraffin crystals forms on the cold surfaces of the discs, and a set of slowly revolving arms carrying scrapers which press against the disc faces serves at once to scrape off the deposit of paraffin, and to expose fresh surfaces to the action of the cold. Extending along the bottom of the trough there is

a well-portion or channel in which the semi-solid mass accumulates, and being there stirred by rotating arms on a lower shaft it is readily discharged by a pump from the cooler through a pipe to filter-presses.

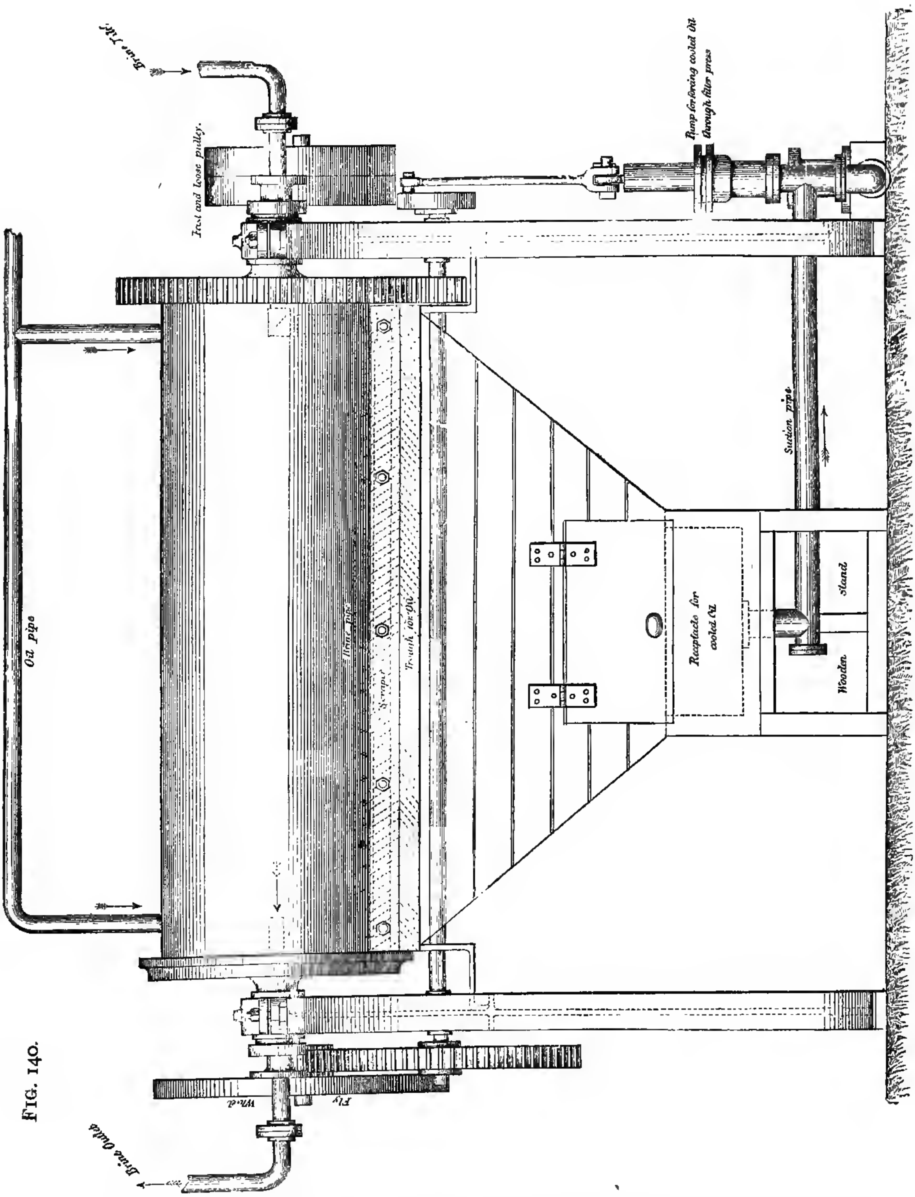


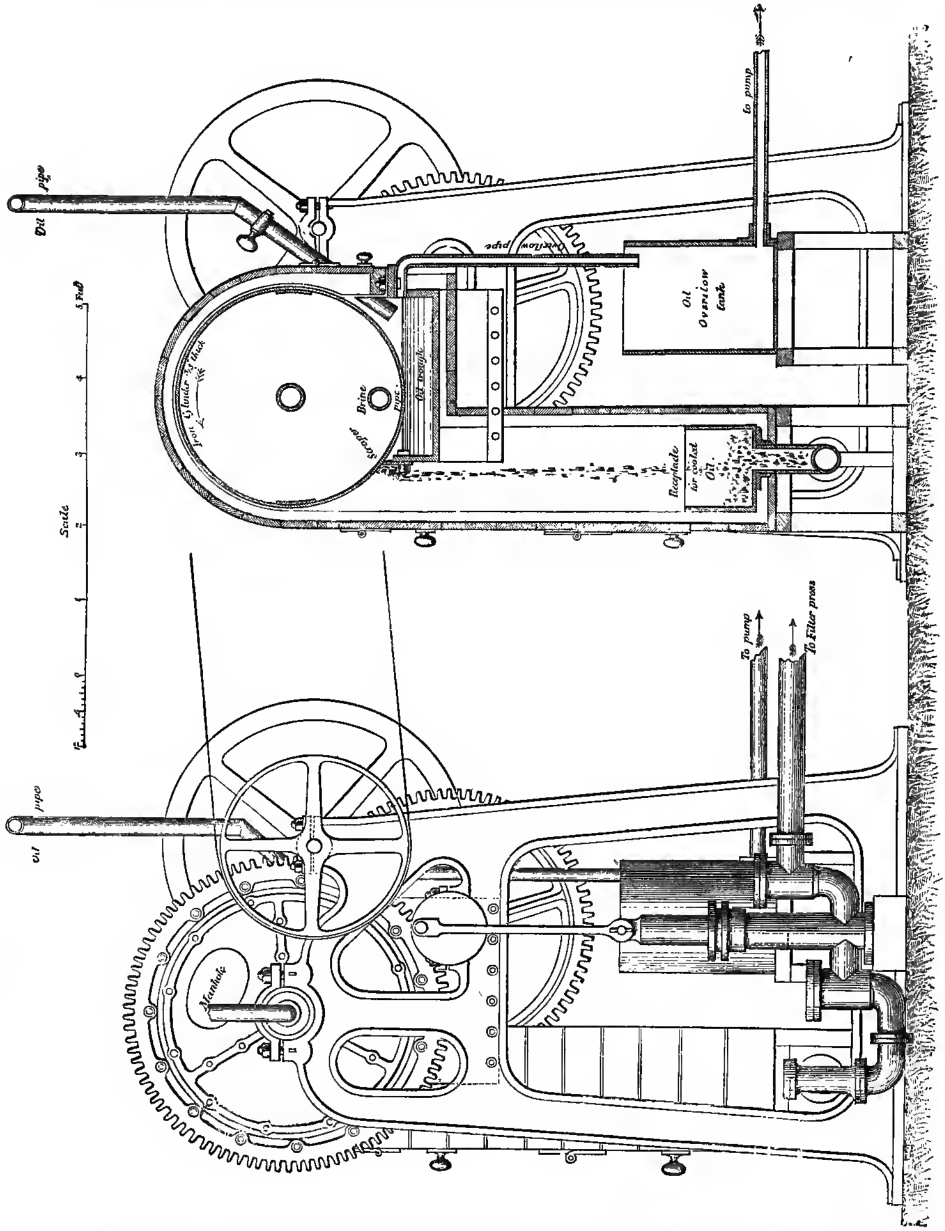
FIG. 140.

ELEVATION (WOODEN CASING REMOVED).
Revolving Drum Refrigerator.

The cooling arrangement adopted by Mr. Beilby, Figs. 148 and 149 (pp. 239 and 240), consists of a series of rectangular cells, sixteen feet long, eight feet deep, and one foot wide, built up vertically in blocks, say, of ten cells each. Between each pair of oil-cells is an interspace or intermediate cell through

which cold brine or cold air is caused to circulate. A period of four days is allowed for the slow cooling of the oil and gradual crystallisation of the paraffin. At the expiration of that time the oil-cell contains a solid slab,

FIG. 141. FIG. 142.



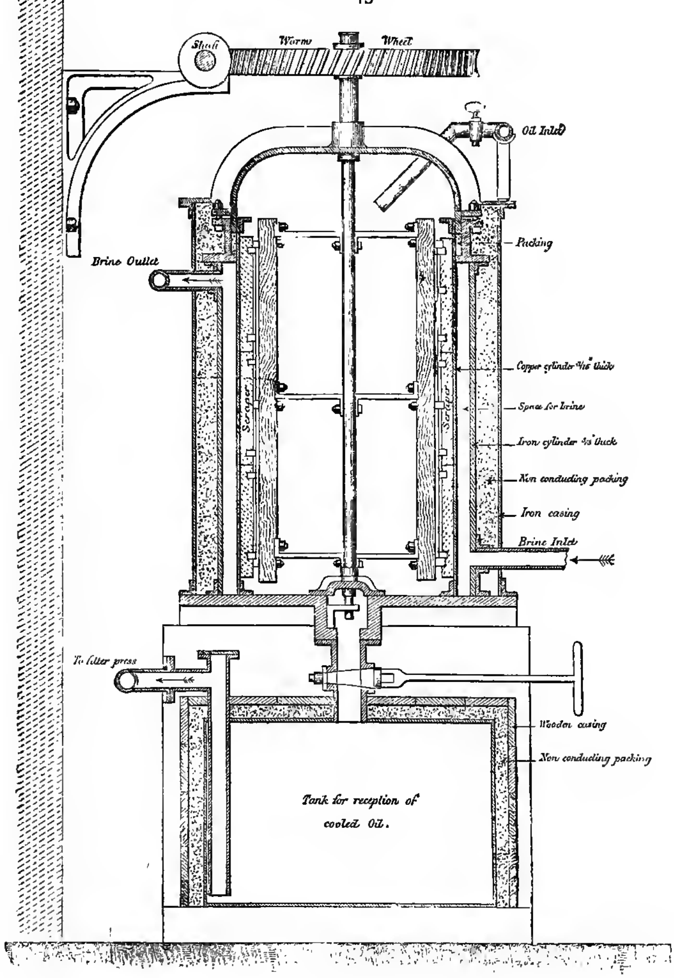
END ELEVATION. CROSS SECTION SHEWING WOODEN CASING.

Revolving Drum Refrigerator.

the crushing and shearing strength of which is 3 lbs. per square inch. Along the bottom of each oil-cell extends a screw, one foot in diameter, the shaft of which passes through a stuffing-box at one end of the cell, and on this screw being rotated by worm-gearing the slab of oil and paraffin is sheared

away and the mashed material is discharged through a sluice valve at the other end of the cell; the descent of the slab by gravitation upon the screw as the shearing proceeds being assisted by making the cell somewhat wider at the bottom than at the top. From the sluice valve, the mass is pumped through a series of horizontal filter-presses, and as the mass still contains oil, it is further subjected to a pressure of $2\frac{1}{2}$ tons per square inch in

FIG. 143.



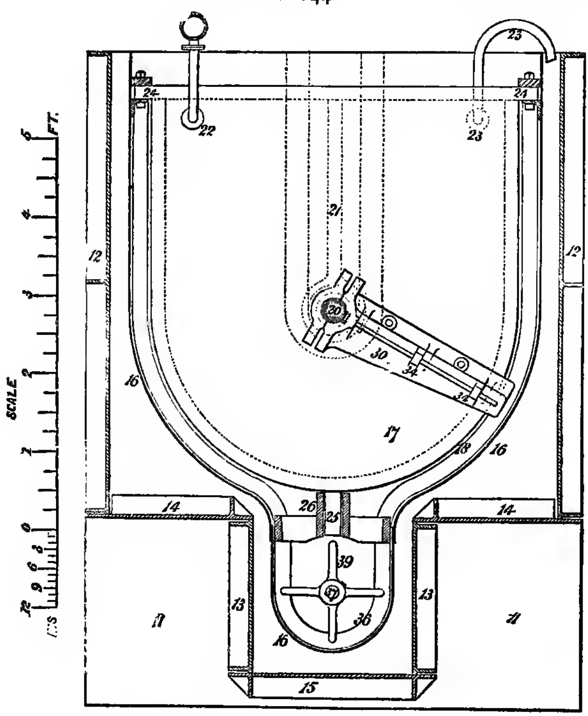
UPRIGHT CYLINDRICAL REFRIGERATOR.

hydraulic presses, the paraffin thus obtained being in the form of a hard cake, known in the trade as "scale."

The crude paraffin was formerly refined by being several times recrystallised from shale spirit, subjected to pressure in a hydraulic press, steamed to drive off the spirit, and treated with animal charcoal; but this method of refining has almost entirely given place to what is known as the "sweating" process, which may be described as follows:—The paraffin, in the requisite

proportions of hard and soft scale to give the desired melting point, is melted and run into pans, so as to form cakes about 18 in. by 12 in., and these are allowed to cool. The cakes are then placed in the "sweating house," or hot chamber, which is provided with a series of racks, supporting thick sheets of matting, on which the cakes are laid. The temperature of the chamber is raised by means of steam-pipes to within about 3° of the melting point of the desired product, and the cakes are exposed to this temperature for a few hours, or until they have, by fractional fusion, parted with the oil and low-melting point, or soft, paraffin which they contained. The residual cakes are then melted, and the fused paraffin intimately mixed with powdered animal charcoal and filtered. The purified product may then be run into trays so as to form cakes, or direct into the candle moulds.

FIG 144.

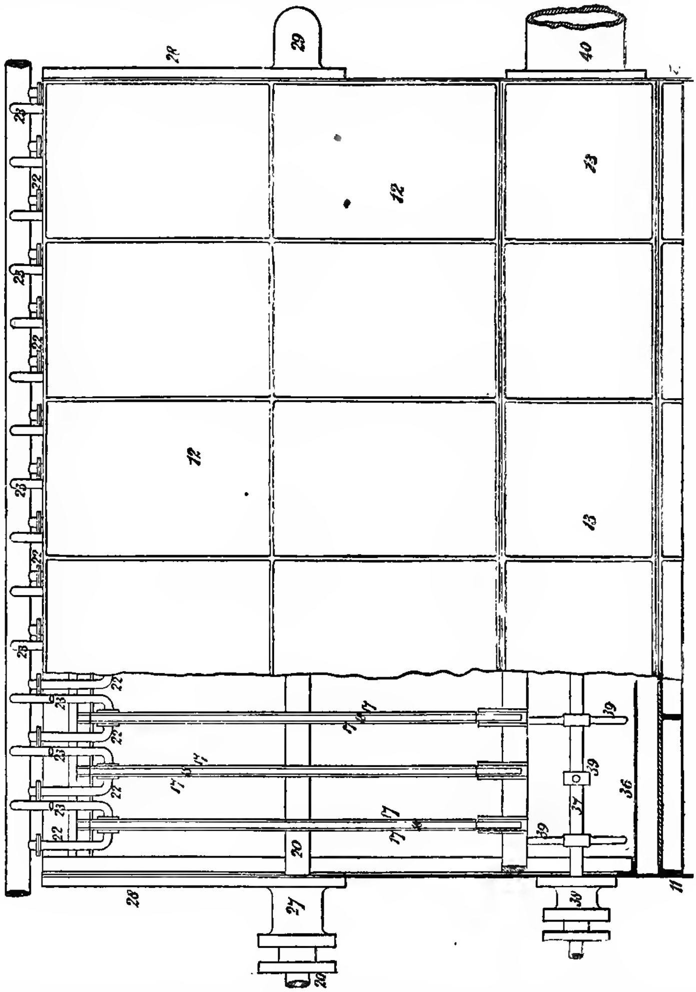


Henderson's Cooling Apparatus.

Recently Messrs. Tervet and Allison patented an arrangement for the cooling and sweating of paraffin, designed to economise labour and admit of the handling of the material in larger quantities. The plant employed consists of a cooling and a sweating house, each subdivided into three sections, so that three qualities of paraffin may be treated. In the cooling or outer chamber are arranged in each section twenty cast-iron enamelled pans (ten on each side of the chamber), 20 to 30 feet (according to circumstances) in length, 30 inches in width, and 2 inches in depth. In these pans are placed sheets of canvas slightly longer than the pans, to allow of an attachment being made, the pans being then filled with melted paraffin, which is allowed to cool. On each side of each section of the sweating or inner chamber are fitted ten shelves of corrugated steel plate, corresponding in position and length to the cooling pans. These plates are inclined to the

front, and are provided with gutters to receive the drainage. The requisite temperature of the section of the sweating chamber is usually maintained by exhaust steam. At the end of each section is fixed a small hand-winch by means of which the cooled paraffin, adhering to the canvas and forming a long cake, is drawn from the cooling house into the sweating chamber and slowly passed over the corrugated plates, the cake cracking, and freely parting with the oil and low melting point paraffin in this operation. The

FIG. 145.



Henderson's Cooling Apparatus.

hand-winch also draws the cakes from the sweating house, and the paraffin then passes through a hopper into a boiler where it is melted, and blown by steam pressure to the "charcoalisers," after which it is filtered in the usual manner. The drainage from the cakes is similarly cooled and sweated for the production of a material of lower melting point.

The latest arrangement for the refining of crude paraffin by sweating is the patent of Mr. M. Henderson. In carrying out this system, a stove or chamber is fitted with a number of horizontal trays, about 21 feet in

length and $6\frac{1}{2}$ feet in width, supported in vertically arranged sets on an iron framework. Each tray is provided with a horizontal diaphragm of iron gauze, covered with a woven fabric to act as a strainer. The stove is furnished with steam pipes for the purpose of heating it, and large doors

FIG. 146.

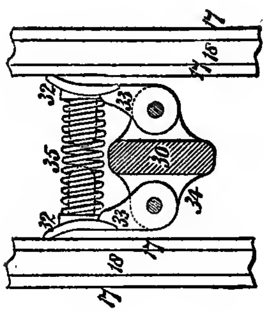
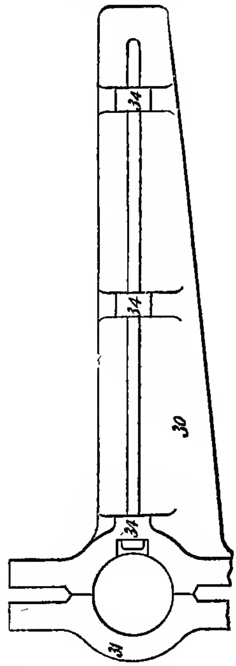


FIG. 147.



Henderson's Cooling Apparatus.

DESCRIPTION OF FIGURES.

Figs. 144 and 145 are transverse and longitudinal vertical sections. Figs. 146 and 147 are enlarged views of details.

11. Vertical wrought-iron end plates of outer shell of trough.

12, 13. Flanged cast-iron side plates of same.

14, 15. Bottom plates of same.

16. Inner shell of sheet iron.

17. Discs of thin metal, riveted on a frame, 18, forming transverse vertical casings.

20. Shaft carrying scraper-arms. 21. Bar to divide the upper part of space between discs, and thus cause proper circulation of cooling fluid.

22. Inlet pipes for cooling fluid. 23. Outlet pipes for cooling fluid.

24, 25. Projections to hold 17 and 18 in position.

26. Cast-iron frames in which sockets are formed to receive 25.

27. Stuffing-box for shaft. 28. Plates covering slots.

29. Bearing piece. 30. Scraper-arms. 31. Cap to fix scraper-arm to shaft. 32. Scrapers. 33, 34. Scraper lugs.

35. Helical springs to press outer scraping edges against discs, 17.

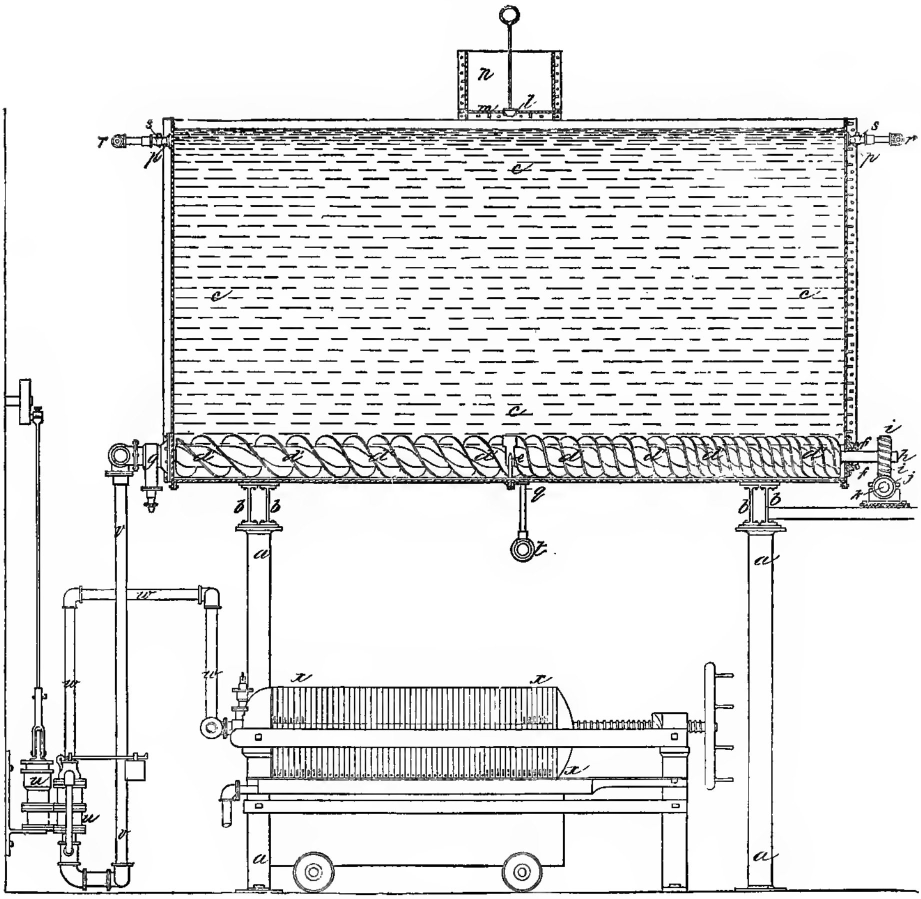
36. Channel into which the congealed paraffin descends.

37. Lower shaft passing out through stuffing-box, 38, and carrying blades on arms, 39.

40. Discharge pipe.

and ventilators to cool it when required, the operations of cooling and heating being conducted in the one chamber. Cold water is first run into the trays to a depth sufficient to cover the strainers, and then the paraffin, previously melted in a pan outside the stove, is run in upon the surface

FIG. 148.



Beilby's Cooling Apparatus.

DESCRIPTION OF FIGURES.

Fig. 148 is an end elevation of the apparatus, wherein one of the cooling cells or units is shown in section.

Fig. 149 is a front elevation with parts shown in section.

The apparatus is supported on girders *b*, carried on the columns *a*.

The unit of apparatus consists of a cell *c*, having other cells, *d*, on the sides thereof, for the purpose of absorbing heat from the liquid paraffin undergoing cooling in repose in the cell *c*.

The figures represent a battery consisting of a series of such cells.

d^1. Rotating screw or helical cutter.

f. Liquid-tight bearing.

g Outlet valve.

h. End of shaft carrying worm-wheel *i*, which engages with worm or tangent screw *j*. on common shaft *k*.

l. Inlet through lower plate *m*, of reservoir *n*.

o. Rods attached to plugs closing inlets. o^1. Auxiliary rods attached to plugs.

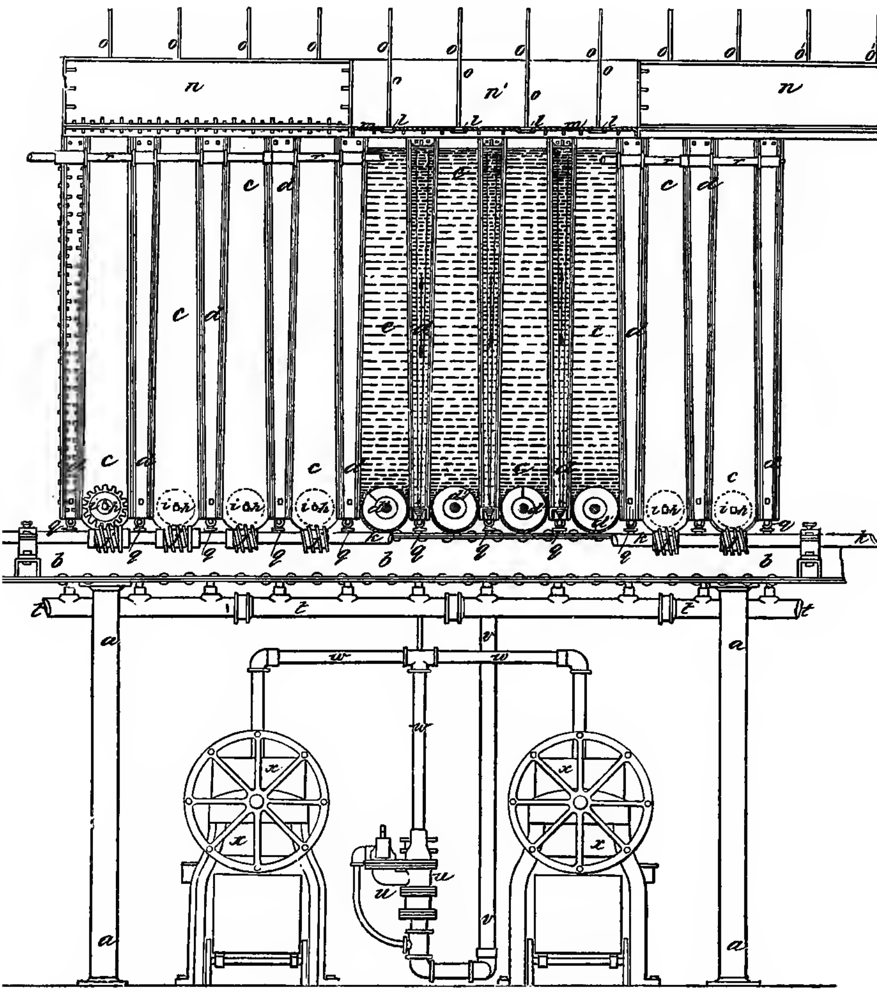
q. Cold water inlets, connected with cold water main *t*.

p. Cold water outlets, provided with valves or cocks *s*, and connected pipes *r*.

u. Pump. *v*. Pipe to pump. *w*. Pipe to filter-press *x*.

of the water, so as to fill the trays. The paraffin is allowed to cool, and when it has become solid the water is drawn off. The doors and ventilators of the chamber are then closed, and steam turned on to the heating coils. As the temperature gradually rises, the liquefied impurities drain off through suitably arranged adjustable outlets beneath the strainers. When the paraffin has been sufficiently subjected to the sweating process,

FIG. 149.



Beilby's Cooling Apparatus.

the temperature of the chamber is increased by the use of auxiliary steam pipes, and the residual paraffin becoming melted, passes through the strainers and runs through the outlets into a receiving tank outside the chamber. From this tank, the paraffin, which is maintained in a liquid condition, is transferred by pumping, or other means, to the decolorisers to be treated with charcoal, the usual filtration completing the process. It is claimed for this system that considerable economy of labour is effected by the adoption of the arrangements described for the charging and discharging

of the trays and conduct of the operations of cooling and sweating in the same chamber; also that large quantities of material can thus be handled with plant of moderate extent.

A process for the removal of the oil from crude paraffin which was devised by Mr. Sterry, consists in kneading the impure paraffin in a weak solution of alkaline soap at a temperature about ten degrees below the melting point.

As the result of the adoption of improved retorts for distilling the shale, coupled with greater care in the distillation of the crude oil and the employment of more powerful refrigerators, the percentage yield of paraffin has been greatly increased, and the quality of the heavy oils improved.

The lubricating oil expressed from the paraffin is fractionated by distillation, and the products are purified by treatment with acid and alkali.

The process adopted in the refining of shale oil is more complicated than that which is employed in obtaining the various commercial products from petroleum, and the details are varied according to circumstances. No attempt has therefore been made in the foregoing description to give more than a general outline of the principles upon which the manufacture is conducted. The object of the shale-oil refiner is, like that of the petroleum refiner, to obtain, by the classification of the hydrocarbons present, the largest yield of the products for which he has the best sale.

In the following tables will be found the approximate percentage yield from the crude oil of the products specified at two of the principal refineries in Scotland, but the percentages are often purposely varied to suit the requirements of the market.

YOUNG'S PARAFFIN LIGHT AND MINERAL OIL COMPANY.

	Per cent.
Gasolene	0.25
Naphtha sp. gr. .700 to .760	5.75
Burning Oils:	
No 1, sp. gr. .802 to .804, F.P. 110° (Abel test) „ 2, „ .810 „ .812, „ 100° „ Crystal (No 1, finished by chemical treatment) Lighthouse oil, sp. gr. .810 to .820, F.P. 140° (Abel test)	38.00
Lubricating oils of various specific gravities	14.50
Paraffin (solid)	11.00
Loss	30.50
	100.00

BROXBURN OIL COMPANY.

Naphtha, sp. gr. .730	5.00
Burning Oils:	
Petroline, sp. gr. .800 to .802 No. 1. „ .808 „ .810 Lighthouse oil, sp. gr. .810	37.28
Lubricating oils	17.40
Paraffin (solid)	12.52
Loss	27.80
	100.00

The commercial products obtained from shale oil differ chemically from the corresponding products of the distillation of American petroleum in containing a larger proportion of hydrocarbons of the olefine series, and a smaller proportion of those of the paraffine series.

In the foregoing pages an attempt has been made to present, within a comparatively limited compass, the salient features of an industry which in respect to its magnitude and rapid development is without parallel. Having regard to the scope of this volume, the subject has been dealt with from the point of view of the employment of liquid and solid hydrocarbons as a source of light, and such descriptions of crude oil or petroleum products as are intended for other uses have been referred to only incidentally and in cases where it appeared that such reference was essential to a proper appreciation of the character of the industry as a whole. At the same time, it should be pointed out that vast as is the consumption of mineral oils in lamps, and of paraffin in the form of candles, the manufacture of products suitable for use as lubricants also constitutes a business of immense industrial importance, whilst the growing employment of petroleum as liquid fuel and as a source of gas for illuminating purposes opens up a field of incalculable magnitude. These considerations may be regarded as justifying the view that this immense industry which at present supplies the whole civilised world with what has become one of the necessaries of life, may be regarded as being still in its adolescence, and as being not unlikely to reach a stage of development which will justify this being known as the age of petroleum. In a subsequent section, the history of the evolution of the mineral oil lamp will be traced with a completeness which has not hitherto been attempted, and a full description will be given of the ingenious appliances which have been introduced within recent years for the use of this oil as an illuminating agent.

SECTION V.

LAMPS

(*OTHER THAN GAS AND ELECTRIC*);

OIL GAS; AIR GAS MACHINES AND CARBURETTORS.

BY

BOVERTON REDWOOD.

CHAPTER I.

Historical Description of Lamps for use with Fixed Oils.

A SHELL from the sea-shore or the skull of an animal was probably employed as a receptacle for the oil of the primitive lamp, but the specimens of lamps of stone, earthenware, and metal to be found in our museums indicate that at a very early date attention was largely directed to their manufacture by the more civilised nations, and the artistic merit of the antique Roman and Grecian lamps is well known. These lamps consisted of a shallow receptacle

FIG. 150.

FIG. 151.

FIG. 152.

for the oil, with one or more nozzles or wick-holders at the side, and were commonly of the form illustrated in Fig. 150. Earthenware lamps of similar construction, but of less elegant form, are still employed in India, provincial Russia, Galicia and elsewhere. Specimens of these lamps in the possession of the writer are represented in Fig. 151, and primitive lamps of hammered iron, one of which was found by the writer in use at Cordova, in Fig. 152.

Lamps of this description possessed several defects. They emitted much smoke and gave but a dim light, which gradually diminished in intensity as the oil was consumed; moreover, the light was obstructed in some directions by the oil reservoir.

Various ingenious arrangements for maintaining a constant oil level were suggested many centuries ago. Thus, Hero of Alexandria (200 B.C.) devised a lamp, Fig. 153, in which the raising of the oil was effected by the pressure of a liquid of greater specific gravity acting through a column of air. A solution of brine in a chamber *C* flowing through a tap drove the air from a vessel *D* through a pipe *N* into an oil reservoir *A*. The oil was thus forced from the reservoir *A* into the bird's beak, whence it dropped into a receptacle *B*, which supplied a wick burning at the tail. This arrange-

FIG. 155.

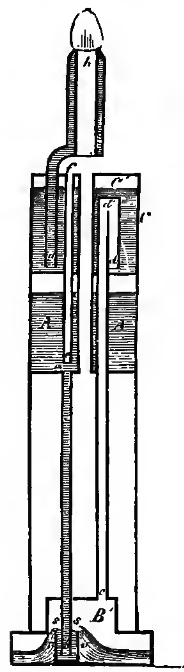


FIG. 153.

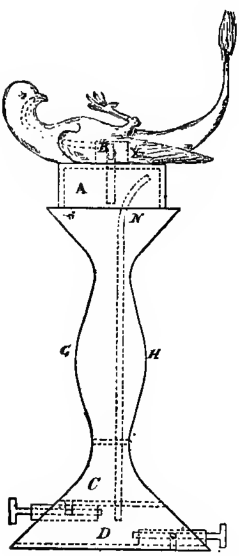
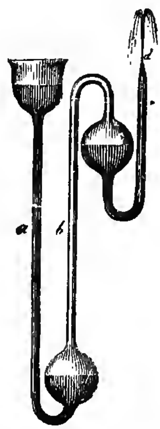


FIG. 154.



ment, an adaptation of the well-known Hero's fountain, Fig. 154, in which the pressure of liquid in a tube *a* acts through a column of air *b*, to drive liquid from a vessel *c*, through a jet *d*, was employed, with some modifications, by King in his "hydro-pneumatic" lamp (Rees' "Encyc." 1819; article, Lamps), and by Barton in 1809 (Patent No. 3272).

Fig. 155 shows Girard's "fountain" lamp, which is also constructed on this principle. The weight of the oil in a reservoir *A* operating through the column of oil, *a*, *b*, slightly compresses the air in a vessel *B′*, and the pressure thus exerted through the medium of the imprisoned air forces the oil from a vessel *C* through a tube *g* to the burner *h*. The tube *c*, *d′*, *d*, connecting the vessels *B′ C* is bent like a siphon at the desired distance from the upper end, to reduce the height to which the oil would otherwise be raised, the reduction in height corresponding with the distance that the end *d* is below the surface of the oil in the vessel *C*.

To prevent the gradual diminution in pressure due to the falling of the

oil level in A, and the rising of the oil level in B', the vessel A is fitted with an air-tube $e\,f$, while the exit end of the tube $a\,b$ within the vessel B' is surrounded by a short tube of somewhat greater diameter, forming an annular space $s\,s$, which is quickly filled with the oil. The effective column of oil is thus that portion between the lower end of the air-tube $e\,f$ and the top of the annular space $s\,s$, and this length remains constant until the level of the oil sinks below e in the vessel A, or rises above $s\,s$ in the vessel B'.

What is known as the bird-fountain principle, in which the passage of air into the reservoir permits escape of the liquid, appears to have been applied to lamps as early as the sixteenth century by Cardan (D'Allemagne,

FIG. 156.

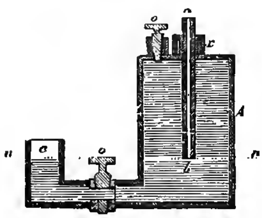


FIG. 157.

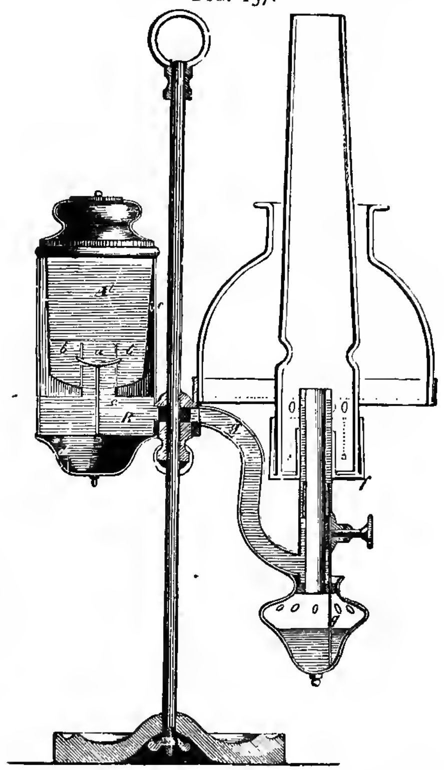
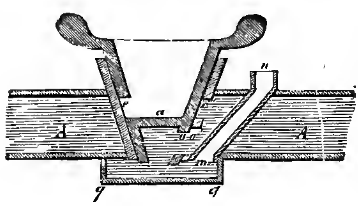


FIG. 158.



"Histoire du Luminaire," 1891, p. 238; and Rees' "Encyc." 1819, article, Lamps), and later by Miles in 1781.

Fig. 156 represents an arrangement of this charaeter. A is an oil vessel with a stopcock o, an air-tight stopper o', and a tube $a\,b$, open at both ends, inserted through an air-tight stuffing box x. The stopcock o being closed and the stopper o' withdrawn, the vessel A is filled with oil. On the stopper being replaced, and the stopcock opened, the oil will rise in the branch c to the level $n\,n$, corresponding with the lower end of the tube $a\,b$. If the burner of a lamp be attached to the branch c, and the oil gradually consumed, the level will remain constant, a few bubbles of air passing from time to time from the lower end of the tube $a\,b$ into the vessel a, and a corresponding volume of oil flowing into the branch c.

Fig. 157 represents a reading lamp embodying this principle. It is provided

with a bottle-shaped reservoir A, having an outlet capable of being closed by a valve a. When the reservoir, having been filled with oil and inverted, is placed in the casing B, the valve is lifted in consequence of its spindle coming into contact with the bottom of the casing. The oil then flows into the casing until on a level with the mouth of the reservoir, and passes to the wick. As it is consumed and the level becomes slightly depressed, air enters the vessel A and permits a little more oil to flow out.

Another application of this principle is made in Caron's stopcock, Fig. 158. The hollow plug of the cock is divided into an upper and a lower compartment by the partition a. Two round oppositely placed openings e and o, one in the upper and the other in the lower compartment, correspond with the apertures e' and o' in the socket of the plug. In the position of the cock represented in the drawing, the upper aperture e is closed, while the lower aperture o is in direct communication with the oil in the circular oil vessel A A. An open tube m n, the lower end of which is at the same level as the burner of the lamp, supplies air as it is required, in the same manner

FIG. 160.

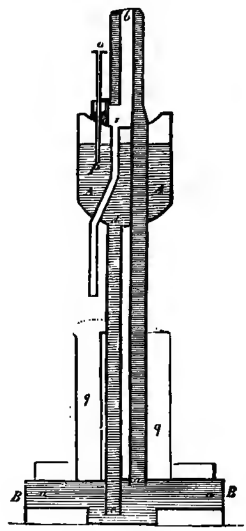


FIG. 159.

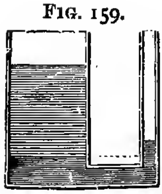
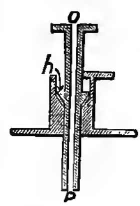


FIG. 161.



as the tube a b in Fig. 156. The supply of oil to the burner is furnished by tubes proceeding from the sunk part of the vessel q q. When the oil vessel requires replenishing, the plug is turned so that the upper aperture e is in communication with A A through e', while the lower aperture o is closed, and thus all connection with the burner cut off.

The principle of the hydrostatic balance, Fig. 159, in which a heavy liquid in one limb of a vessel of the form shown raises a lighter liquid in the other limb to a height dependent on the relative densities of the liquids, has also been applied to lamps for raising the oil to the wick. In the hydrostatic lamp of Thilorier, Figs. 160 and 161, introduced in 1825, the oil is raised from a chamber B by the pressure of a strong solution of zinc sulphate contained in a vessel A; the relative specific gravities of the two liquids being such that a column of oil 15.7 inches in height is supported by a 10-inch column of the solution. The column of oil in the tube a b, at the upper extremity of which the burner is situated, and the column of zinc sulphate solution in the tube e d, above which is the cistern A containing the supply, both terminate in the chamber B, and the flow of solution from A is regulated by

means of the air-pipe *o p* in the manner described in connection with Fig. 155. The cistern *B* is completely filled with the two fluids, the tube *e d* terminating at its lower end below the level *n n* of the zinc sulphate solution. During the combustion of the oil the level *n n* gradually rises until the vessel *B* becomes filled with the solution. A further supply of oil must then be introduced through the burner, the solution being thus displaced and driven back to its former position, while air is allowed to escape from the vessel *A* between the conical collar *h* of the tube *o p* and its seating. The oil which overflows the burner passes through the tube *i* into the movable vessel *q*.

In an arrangement proposed as early as 1698 by Robert St. Clair ("Phil. Trans." 1698, vol. xx. p. 380), the oil was supported at the desired height by floating it upon water, the level of which was gradually raised, as the oil was consumed, by the continuous addition of water in regulated quantity.

In 1787, Kier constructed a lamp having an oil chamber open at the bottom, and floating on salt water contained in a larger vessel. As the oil became consumed, the level of the water rose in the oil chamber, and the increase in the distance between the surface of the oil and the flame which would otherwise have ensued was thus prevented.

In the well-known form of night light in which the wick floats on the surface of the oil, another method of preventing any increase in the distance between the surface of the oil and the flame, is represented.

Another device for furnishing the wick with a uniform supply of oil is exemplified by the "Automaton" lamp invented by Porter in 1804 (Patent No. 2768). This consisted of a rectangular box, Fig. 162, so weighted and balanced that as the oil was burned, the containing vessel gradually assumed the inclined position shown.

In Hero's self-trimming lamp, Fig. 163, the effect of the depression in the oil level was provided against by the automatic raising of the wick by means of a float *G*, acting through rack and pinion gearing.

The oil lamps still used in parts of Spain, are in some cases provided with a rack and pinion for adjusting the position of the reservoir and thus regulating the supply of oil to the flame. This arrangement is shown in Fig. 164, which represents a lamp in the possession of the author.

In Bordier-Marcet's "Astral" lamp, Fig. 165, an annular oil reservoir of large area was adopted with the object of minimising the alteration in the oil level.

Arrangements which obviate the necessity for any adjustment of level by supplying the oil to the flame, otherwise than by capillarity, in quantity slightly in excess of that which is required, have at various times enjoyed considerable popularity. Thus, in the well-known "Moderator" lamp, Figs. 166, 167, 168, the oil is raised by the descent of a piston actuated by a spring. This arrangement was first suggested by Stokes in 1787 (Patent No. 1627), and was subsequently adopted by Allcock in 1806 (Patent No 2903), and Farey in 1825 (Patent No. 5214). The present form of the lamp is due to Franchot, who introduced it in 1836, and patented it in England in that year through the agency of Houghton (Patent No. 7265).

In the lamp figured, uniformity in the supply of oil, notwithstanding the gradually diminishing pressure exerted by the piston, is secured in the following manner. The oil supply-tube C, is constructed in two pieces, one fitting into the other. The lower section, which is of the smaller diameter, passes through, and is attached at its lower end to the piston. The upper section is fixed to the burner and forms a sheath for the lower. A small rod or wire G is fixed in the upper tube and extends as far as the commencement of the lower and narrower tube when the piston is at the bottom of the cylinder. When the spring is wound up and the oil supply tube becomes telescoped, the wire G extends throughout the small tube. Therefore,

FIG. 162.

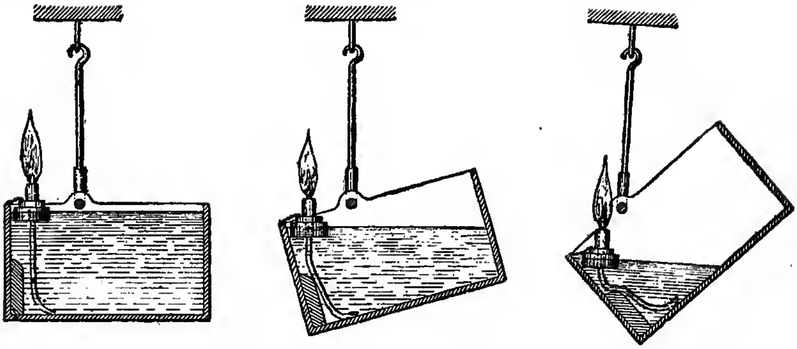


FIG. 163.

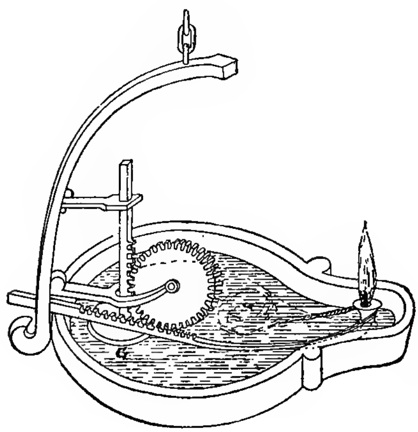


FIG. 164.

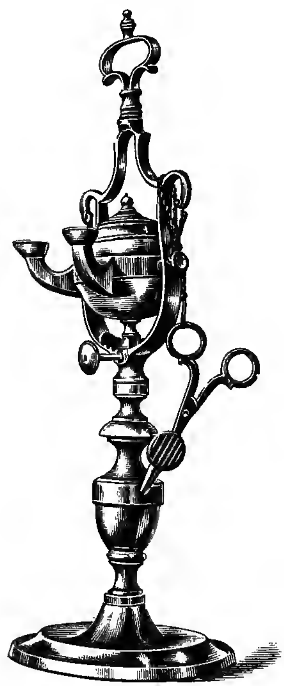
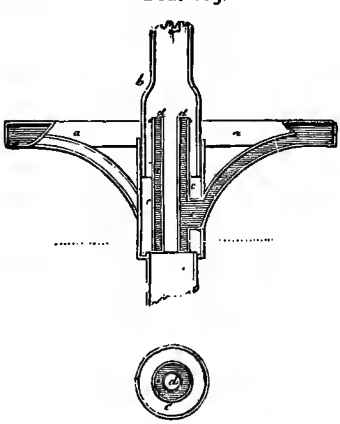


FIG. 165.



when the spring is exerting its greatest pressure, the oil passing to the burner through the annular space between the wire and the tube meets with the maximum amount of resistance from friction, and this retarding force gradually diminishes as the piston descends and the spring exerts less pressure. By adjusting the annular space to the strength of the spring the flow of the oil may be rendered practically uniform. The surplus oil

FIG. 166.

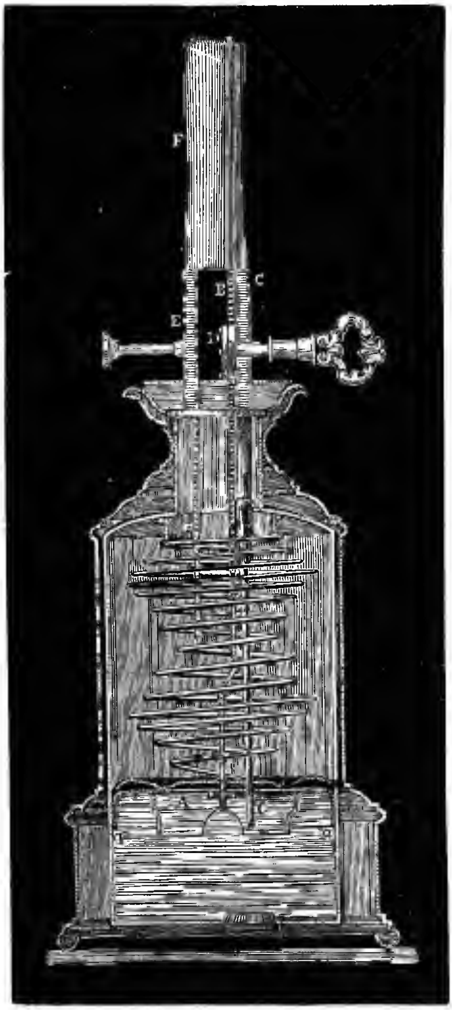


FIG. 167.

FIG. 168.

flowing over the burner returns to the cylinder above the piston, and the fresh charge of oil is added to it. On the piston being raised, a vacuum is created beneath it and the oil above it passes between the leather flange *a a* and the cylinder into the lower space.

A modification of the Moderator lamp, known as the "Diacon," was at one time employed to a considerable extent in America.

A somewhat similar arrangement, patented in 1827 by Roberts and Upton

(Patent No. 5567), said to have heen used for burning seed and common fish oils, is shown in Fig. 169. In this lamp, a weighted plunger *M*, working in the oil reservoir, drives the oil to the burner *B*, through a pipe *G*, provided with a tap *Q*. The excess of oil passes to a cup *H*, whence it flows through a pipe into the upper part of the reservoir. When the piston is raised, a valve in it allows this oil to pass into the lower part of the reservoir.

In Meyer's "Elliptic" lamp (Patent No. 7833, A.D. 1838), Fig. 170, the oil is forced through a tube *D* to the burner by the action of a leather piston *B*, working in a reservoir *A*, and pressed down by a spring *F*. The tube passes air-tight through the piston, and is independently movable. It widens towards the burner, and encloses a capillary silver tube, through which all the oil passes to the burner, the fine bore counteracting the pressure on the oil, and only allowing the required amount to pass. In charging the reservoir, the piston is raised by a rack and pinion worked by a key *I K*.

In a lamp patented in 1840 by Thomas Young (No. 8468), and shown in Fig. 171, the oil is contained in a flexible bag forming the reservoir, which is subjected to the pressure of weights of annular form *j*, the oil being thus forced to the burner through a cock controlled by a float *k*, resting on the oil, which surrounds the wick.

Somewhat later, namely, in 1845, Roberts introduced a lamp (Patent No. 10,842), Fig. 172, in which the oil is raised, not directly to the burner, but to such a height that the capillary attraction of a wick is sufficient to complete the operation, by means of a weighted collapsible vessel *C*, which may be lifted and held out of action when desired. The unconsumed oil is returned to the supply tubes through supplementary tubes at *f*.

None of these methods for supplying the flame with oil enjoyed as wide a popularity as that of Carcel, whose lamp, first introduced in 1798, is still used to a limited extent by the French, and has been largely employed on the Continent as a photometric standard on account of the unvarying light which it furnishes. In this lamp, Figs. 173, 174, 175, the burner is connected with a forked tube *b*, through which the oil is forced from a reservoir *A* by pumps, each of which consists of a box closed above by a diaphragm of goldbeaters' skin fitted to a rod, to which a reciprocating motion is communicated by clockwork *B*. As the diaphragm rises, oil enters the box through a valve at one end, and as it descends, the oil is driven through another valve into the tube *b*. To ensure uniformity in the supply, three pumps *c*, Fig. 174, operating successively, are employed. Each has a separate chamber from which it is supplied, but the space above the exit valves is common to all. The overflow from the burner passes over its edges into the cistern *A*.

The figures represent the Carcel lamp with Penot's improvements. Slight modifications have also been introduced by Gagneau, Nicod, and Careau.

Various devices have been employed for minimising the objectionable shadow cast by the reservoir, which in many cases, as in that of Worms' lamp, Figs. 176, 177, at one time popular on the Continent, obscured a large area round the base of the lamp.

Fig. 178 shows a study-lamp, having the reservoir *a* arranged at the side of and behind the flame, so that no shadow is cast in front, and furnished with a shade *k* carried by a support *m n* to reflect a further amount of light downwards.

In the "Astral" lamp, already referred to, Fig. 165 (p. 247), the shadow is minimised by curving the inner surface of the annular reservoir so as to reflect light downwards. In the "Sinumbra" lamp of Phillips, Fig. 179, the reservoir has a sharp wedge-shaped section, as shown, and no shadow is cast.

FIG. 169.

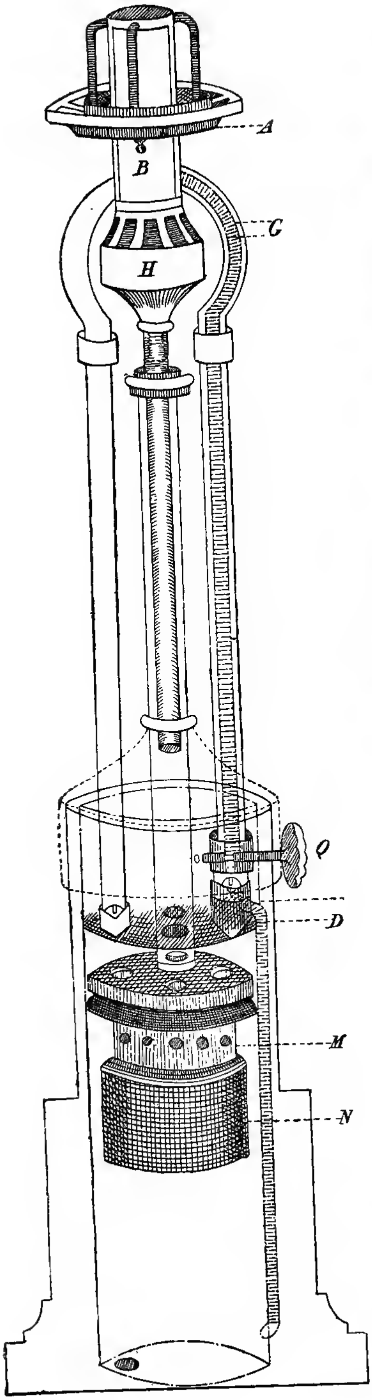


FIG. 170.

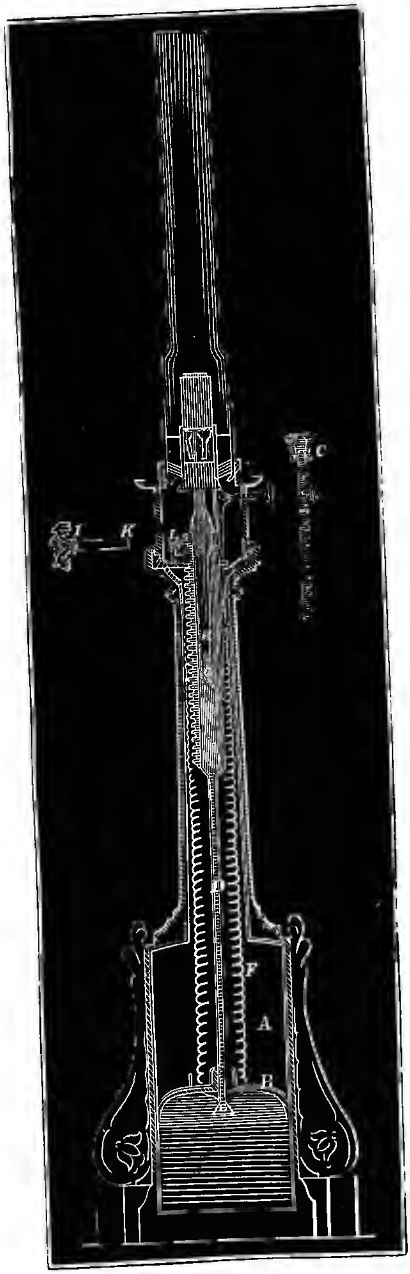


FIG. 171.

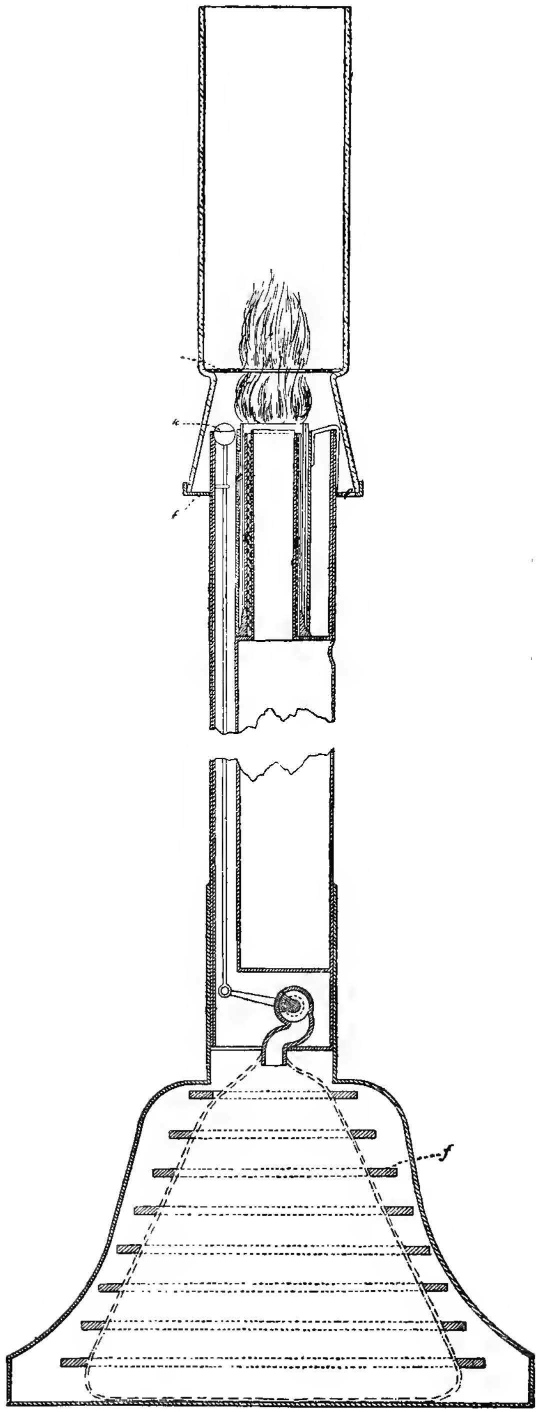
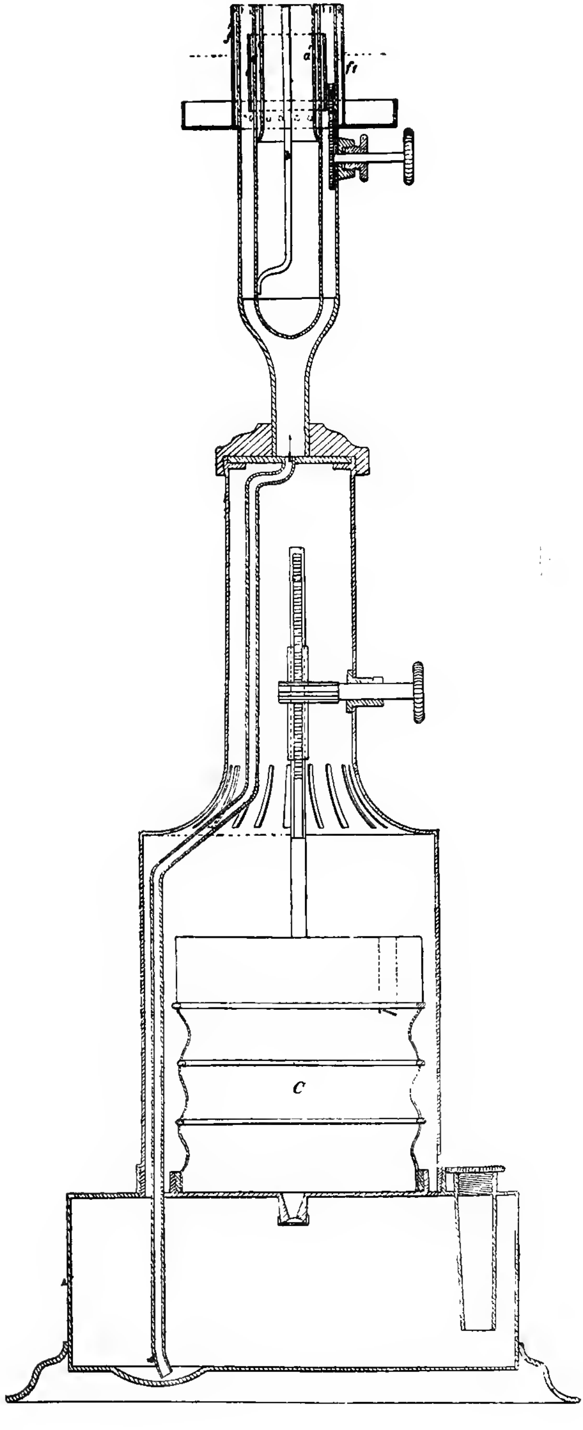


FIG. 172.

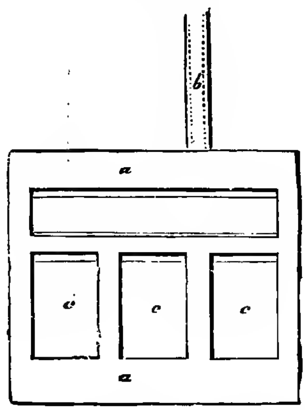


A curious proposal for recovering the unconsumed matters of the flame is that of Besnard, whose "Alembical" lamp or lantern (Patent No. 1332, A.D. 1782) had an "alembical capital" or head, which was said to arrest the smoke and unconsumed vapours and return them to the oil reservoir.

FIG. 173.

Prior to the year 1782, no attempts appear to have been made to regulate the amount or direct the flow of the air which supplies the flame, though the use of the chimney had been proposed by Quinquet. The well-known lamp of Ami Argand, however, introduced in France in that year and patented in England in 1784 (No. 1425), was furnished with a burner having a tubular wick, through and round which the air was directed as shown, in Fig. 180, by the use of a chimney. By

FIG. 174.

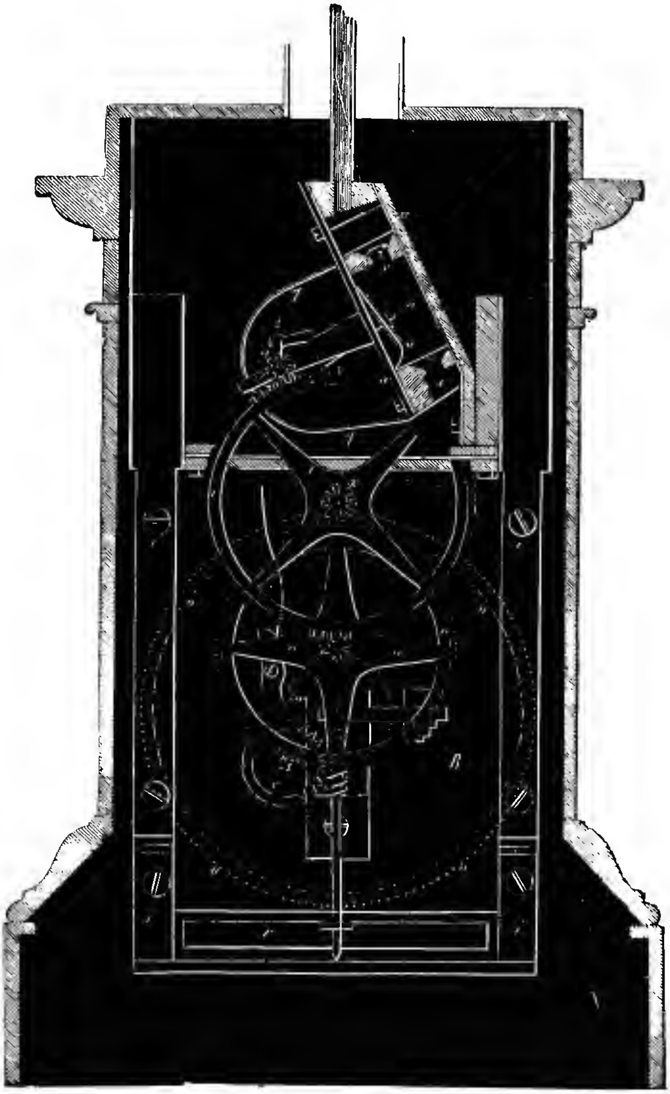


suitably adjusting the size and position of the chimney, the air supply was so regulated and directed on to the flame as to produce enhanced brightness and almost to do away with the smoke. This invention undoubtedly constituted the greatest advance which has ever been made in the construction of lamps, the Argand burner being now used, almost in its original form, for liquid and gaseous illuminants.

The oil in the original Argand lamp was supplied to the wick on the "bird-fountain" principle, and the chimney was simply an iron tube suspended over the flame, but this was soon replaced by a glass chimney. The form of the chimney was in the first instance cylindrical, but it was found that better results were obtained when the lower part was made of somewhat greater diameter than the upper, or when the tube was furnished with a constriction at such a height as to direct the air current on to the flame. The first of these two modifications was

adopted by Smethurst in 1802 (Patent No. 2654), and is usually said to have been invented by him, though it is shown in drawings of French lamps of the time of the Revolution (D'Allemagne, "Histoire du Luminaire,"

FIG. 175.



1891, pp. 386 and 392). A chimney, the lower portion of which was spherical, was introduced in 1808 by Seward (Patent No. 3148).

Following the invention of Argand, numerous devices aiming at more perfect combustion in the flame were introduced. Thus in the "Liverpool" lamp, Fig. 181, the Argand burner is fitted with a rod terminated by a plate *a* which is so adjusted that the air passing through the tube surrounded by the wick,

is deflected against the flame, imparting to it the globular form shown, and producing a more brilliant light.

This plate or deflector *a*, generally known as the "Liverpool button," has been largely employed in other lamps, including Young's well-known

FIG. 176.

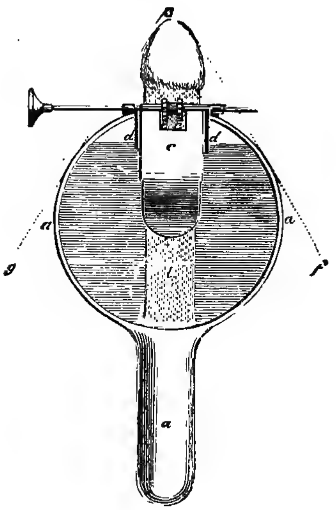


FIG. 177.

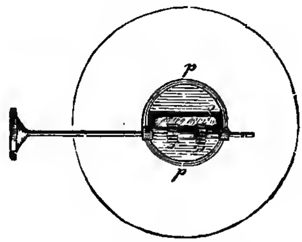
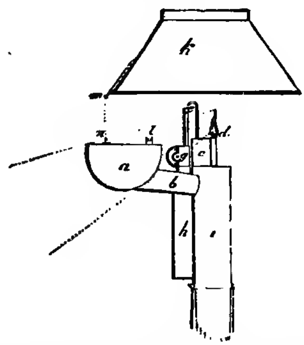
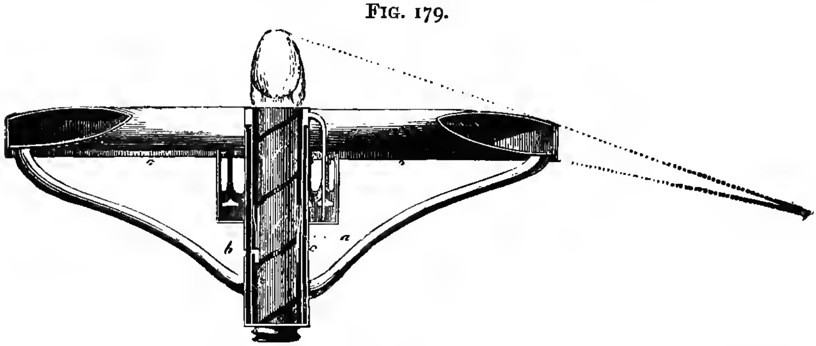


FIG. 178.



Vesta lamp, described in the next chapter (p. 268), and the lamp of Roberts (Patent No. 10,842, A.D. 1845), Fig. 182. Four substitutes for the deflector *e*, Fig. 182, described by Roberts in his specification, are shown in Fig. 183, two being perforated and supplying the air in a steady stream to the

FIG. 179.



flame, and two being trumpet-shaped, one open at the top and furnishing two currents of air, whilst the other is closed at the top and perforated at the sides. An important part of Roberts's invention, foreshadowing the principle of some of the burners now in use, consists in the employment, in addition to the deflector *e*, of two tubes of Wedgwood or other material, *f g*, Fig. 182, which deflect the air on to the outside of the flame. These tubes are

FIG. 180.

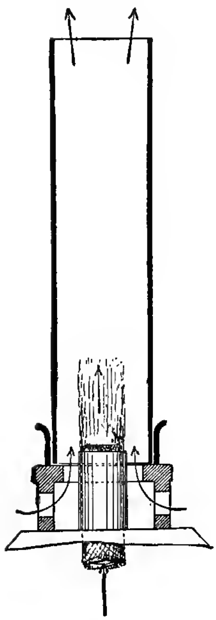


FIG. 182.

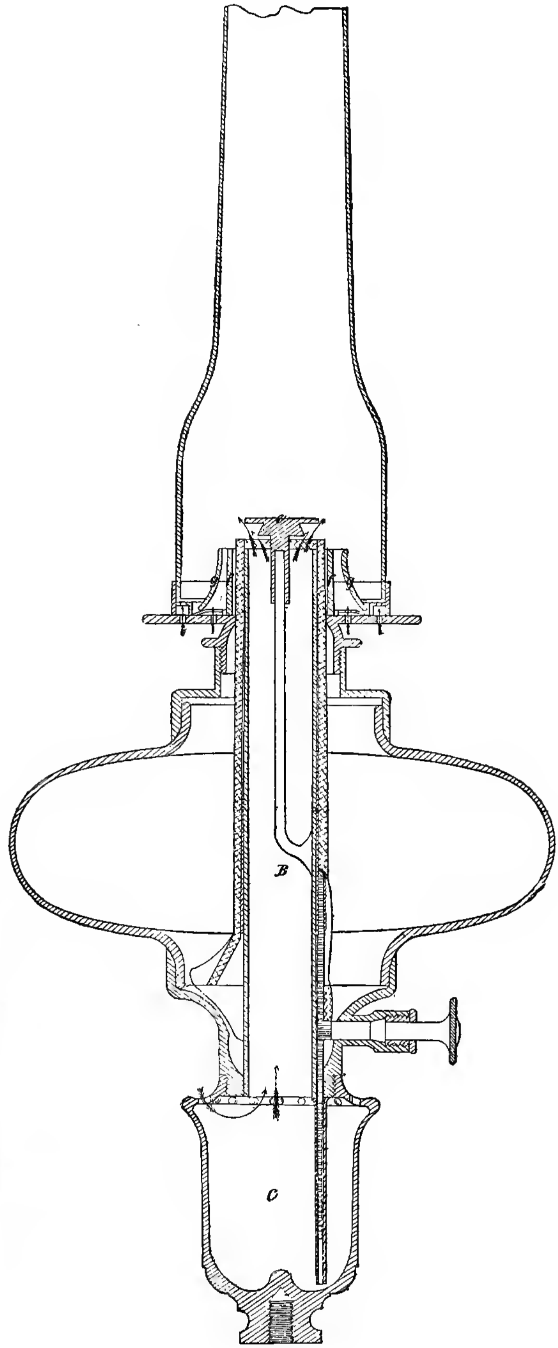
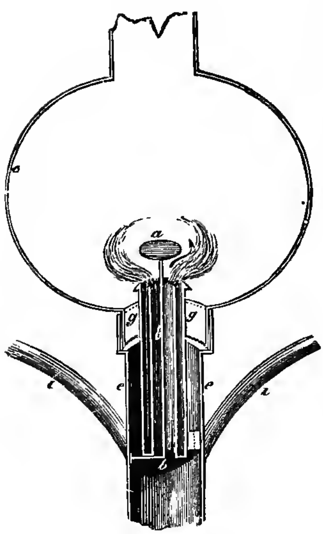


FIG. 181.

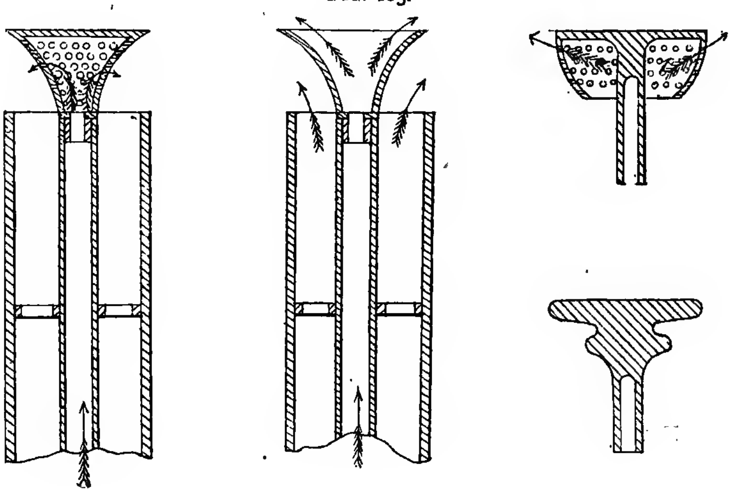


dispensed with in another of Roberts's lamps, the air passing between an outer tube and the wick, and coming out just at the edge of the latter, the tube being perforated at the bottom and gradually narrowing at the top, so that the air escapes in contact with the wick.*

Figs. 184, 185, and 186 exhibit the details of a burner introduced in 1840 by Benkler of Wiesbaden, and extremely popular at one time. The important feature of this burner consists in the insertion of a slightly conical brass ring *d d* between the lower part of the glass chimney *a a* and the upper part *b b*, thus forming a sudden contraction, the opening in the metallic ring being of the same diameter as the wick. The outer air current is thus driven at a sharp angle against the flame, which is rendered narrower and much longer. This burner is stated to have furnished a white light of great intensity.

This principle was also adopted in the Birmingham "Solar" lamp, which was at one time largely used for burning the commoner oils. The air is

FIG. 183.



deflected upon the flame by a metal or glass device, of conical or other shape, *a*, four forms of which are shown in Fig. 187. In form 1, the deflector may be described as the conical top of a metal box; in form 2, it is of glass with a metal ring round the mouth; in form 3, it is carried by an open or skeleton frame; and in form 4, the cone is replaced by a flat metal ring, fixed on a skeleton support, the external edge of which fits the glass chimney.

In the lamp of Roberts & Upton (Patent No. 5567, A.D. 1827) shown in Fig. 169 (p. 251), the air supply is regulated by an arrangement *A*, consisting of a fixed and a movable plate, both similarly perforated so that the perforations may be closed or opened by adjusting the movable plate. In Young's lamp previously described, Fig. 171 (p. 252), the air is supplied to the flame at the requisite point, by the use of a perforated annulus *h*. This arrangement was also employed in a lamp patented by the same inventor in 1841 (Patent No. 9024), the chimney being perforated, or formed in two parts, where the plate is inserted, and having arrangements for raising or lowering it to regulate the air supply. Fig. 188 represents one of

* Roberts had previously, namely, in 1842, patented a compound perforated disc or ring air-deflector, described in the next chapter (see Fig. 200, p. 269).

FIG. 184.

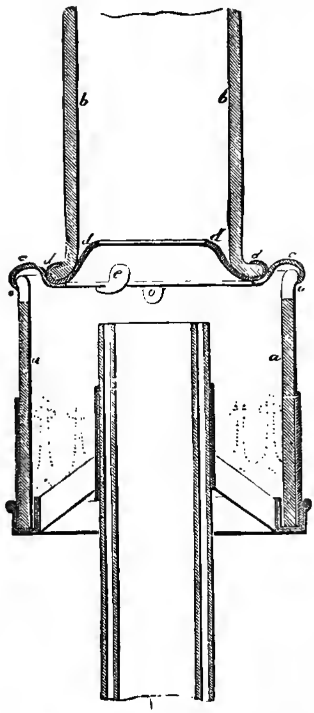


FIG. 185.

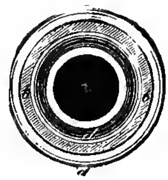


FIG. 186.

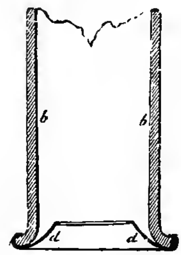
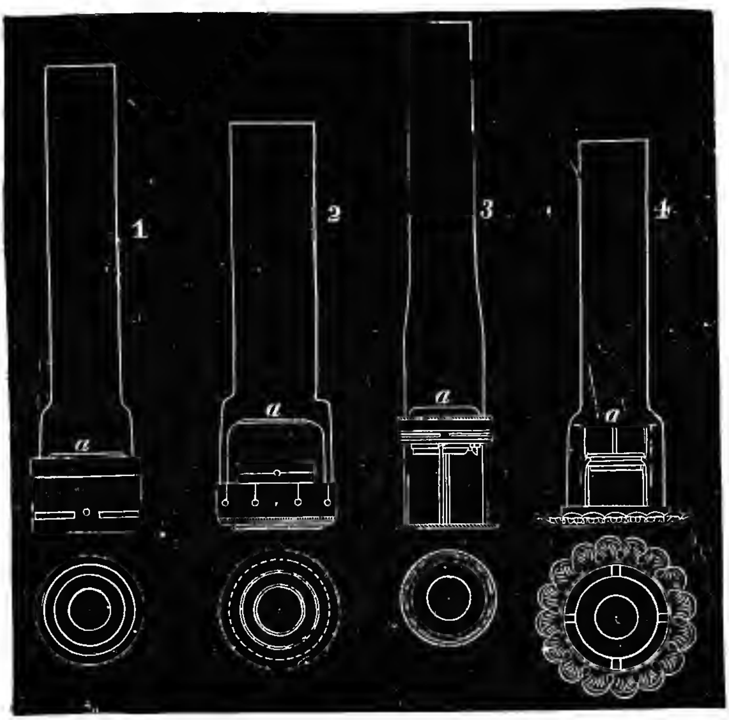


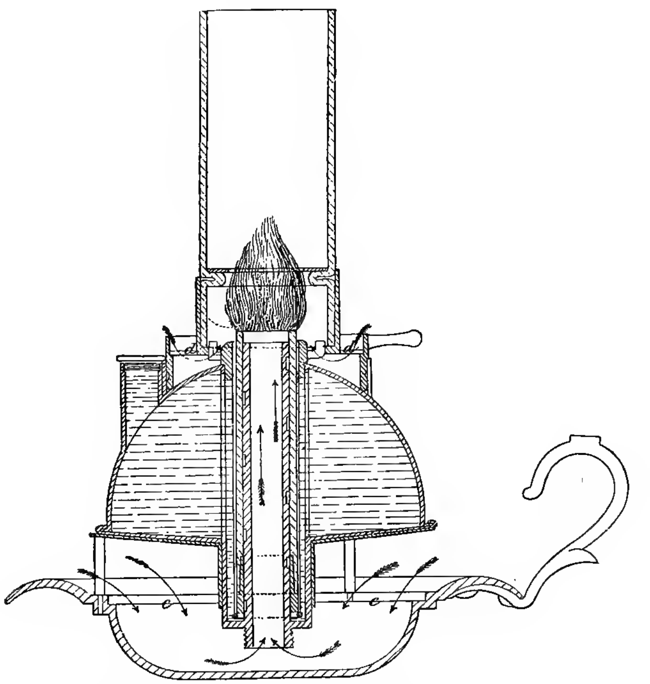
FIG. 187.



Thomas Young's portable lamps in which the air is supplied through wire gauze surfaces *c d*, which break up the currents and minimise the bad effects of sudden draughts.

Fig. 189 is a section of a "spirit" lamp introduced by William Young in 1843 (Patent No. 9989). The air passes through a perforated tube *k*, and through the wick-surrounded tube, the wick being partly cut away—that is, being only semi-cylindrical at the lower part—to permit such passage of the air. One, two or more plates, carried by a bar *u*, deflect the air into the flame. Fig. 190 depicts a hand oil lamp by the same inventor. The air passes to the flame through a short perforated tube F′, fixed to tubes F surrounding and attached to the upper parts of tubes or holders C, carrying the wick or wicks. These wick-carriers are secured to a threaded ring working in an internal thread

FIG. 188.



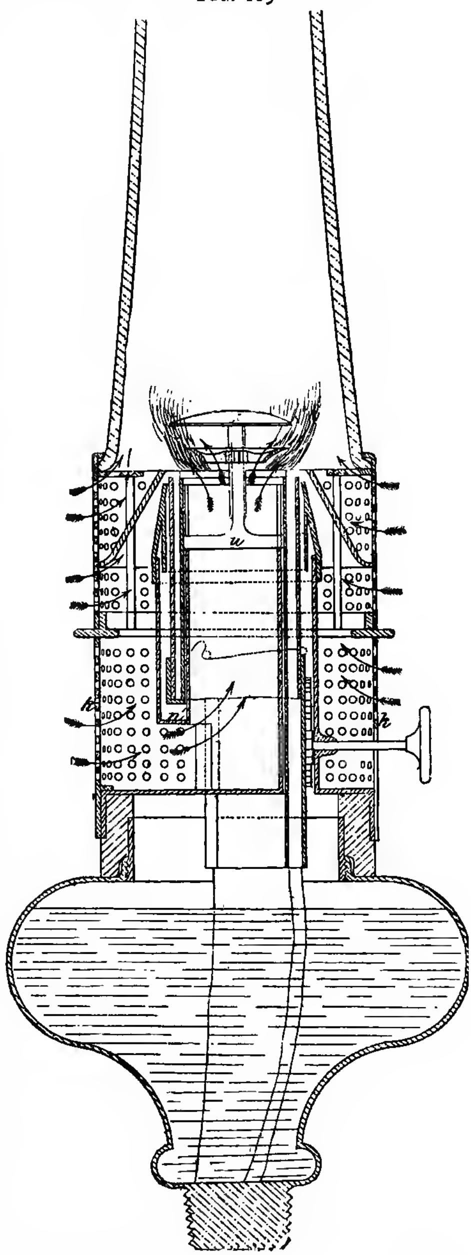
on a fixed tube D, so that when the casing F′ is turned with the tubes F and C, the latter rise or fall in the tube D and thus adjust the wick.

Fig. 191 shows another lamp patented by William Young (Patent No. 1675, A.D. 1857), in which the wick is surmounted by a perforated metal annulus *h*, forming the burner. The air passes to the flame as shown by the arrows, partly up deflectors on a tube *d*, and partly through grooves on a wooden tube *b*. The tube *d* has a horizontal passage into the tube *f*, and on the latter tube the wick-holder *g* slides.

Fig. 192 (p. 263) represents a lamp introduced by James Young (Patent No. 489, A.D. 1858) for railway signalling. The chimney is dispensed with, the lamp case being arranged as shown, and perforated below so that the air is supplied to the burner as indicated by the arrows. Fig. 193 (p. 264) exhibits the form of a lamp invented by King in 1859 (Patent No. 2967), in which the wind-guard *H* is perforated to admit air, and is coned at the

top to direct the current on to the flame. The globe gallery is supported by perforated wings or brass wires *P*, to minimise any obstruction of the passage of air. An invention for supplying oxygen instead of air to the inner tube of the Argand burner was patented in 1839 by Gurney and Rixon (Patent No. 8098).

FIG. 189.



Two arrangements for furnishing a current of air to the flame were introduced respectively by Halpin (Patent No. 8689, A.D. 1840) and Rae (Patent No. 2301, A.D. 1861). In the former, air or oxygen was supplied to the flame by the use of a fan or blower, driven by clockwork or otherwise, or from a reservoir; whilst in the latter, which is shown in Fig. 194 (p. 264), and was intended for burning heavy oils, a current of air was caused to pass up the tubular pedestal of the lamp to the burner *e*, by the use of a small supplementary lamp *f*, placed at its base. It should be noted that an arrangement of bellows for supplying regular currents of air for "lamps, forges, fires or furnaces," had been patented in 1839 by Lamb (Patent No. 8003).

For burning thick crude whale oil, which will not ordinarily pass up the wick, the lamp shown in Fig. 195 (p. 265) was introduced by Parker in 1838 (Patent No. 7682). The reservoir, which acts on the bird-fountain principle, surrounds the upper part of the chimney, which is made of metal, so that the oil, under the influence of the heat to which it is subjected, becomes sufficiently fluid to flow easily. The lamp has a stationary wick which is renewed each time the lamp is used, and the chimney is adjustable by a rack and pinion so that the draught may be regulated.

A proposal to increase the luminosity of the flame by surrounding the lower part with a wire spiral, was made in 1840 by Thomas Young (Patent No. 8468)

FIG. 190.

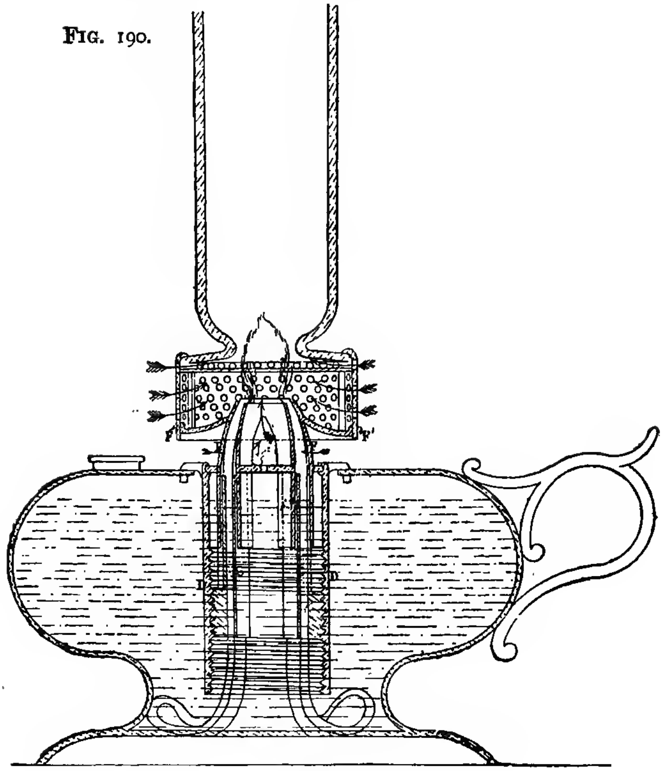
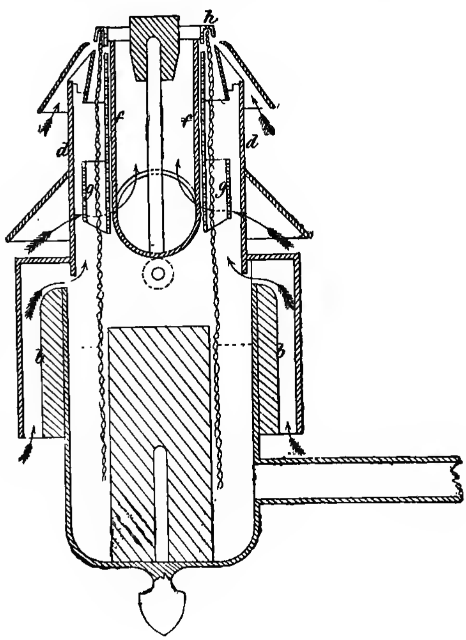
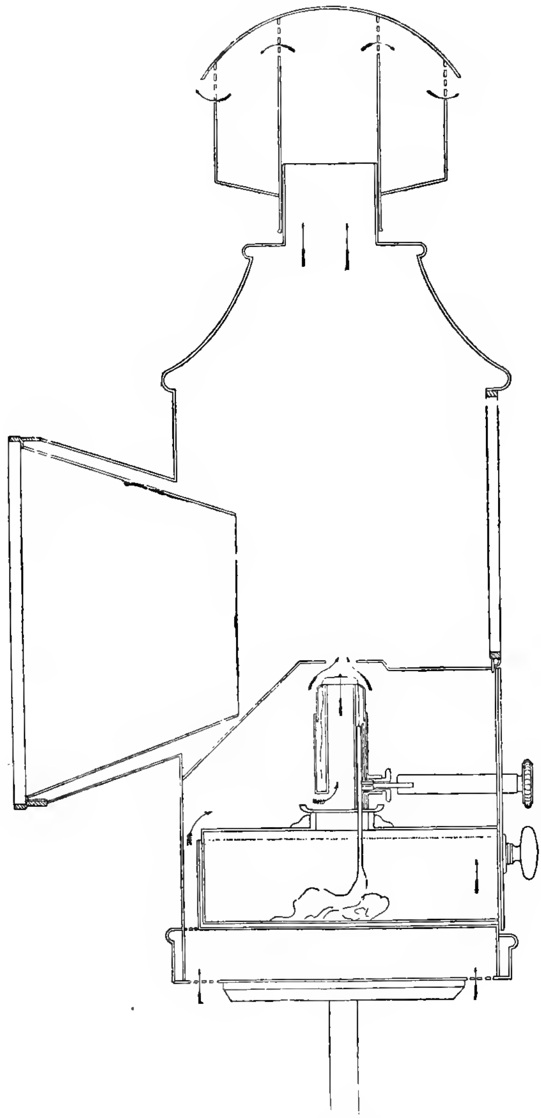


FIG. 191.



Attention was directed at a very early date to the wicks of lamps. The old Roman lamps had wicks of oakum or Carpasian flax, and the lamps employed by the vestal virgins are said to have had wicks of asbestos. As

FIG. 192.



early as the year 1684, Dr. Robert Plot, in an almost forgotten paper read before the Philosophical Society of Oxford (see "Phil. Trans. 1684," p. 806), proposed for sepulchral or perpetual lamps, the use of wicks of asbestos or of gold or other metallic wire "which will lick up oyl as well as any other wick," though he states that a wick of iron wire is not good.

In 1822, A. and D. Gordon (Patent No. 4638) proposed the use of wicks composed of bundles of threads or capillary tubes of platinum, gold, silver, copper, glass, &c., bound together with metal gauze or wire; and in 1845 Roberts (Patent No. 10,842) suggested the employment of wicks of bamboo, cane or porous wood, and of an asbestos wick fitted between two concentric tubes perforated below for the passage of the oil.

The principal improvements, however, related to the cotton wick. The flat ribbon wick, which appears to have been introduced in 1773 by Leger,

FIG. 193.

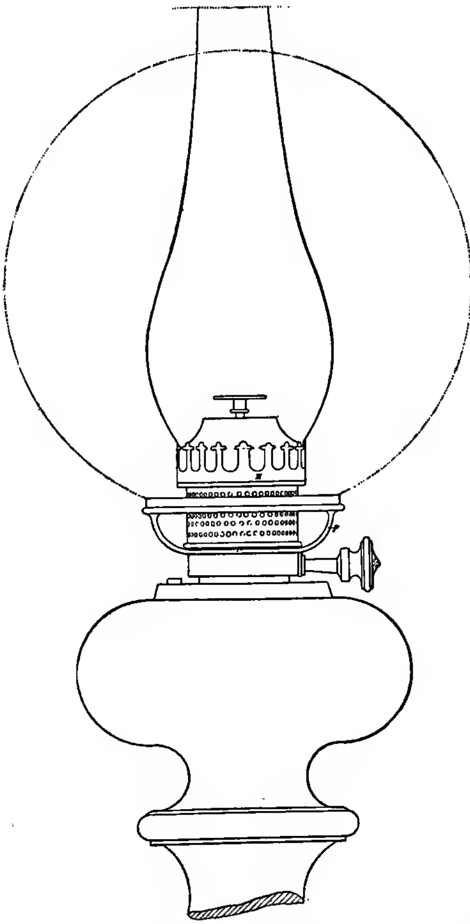
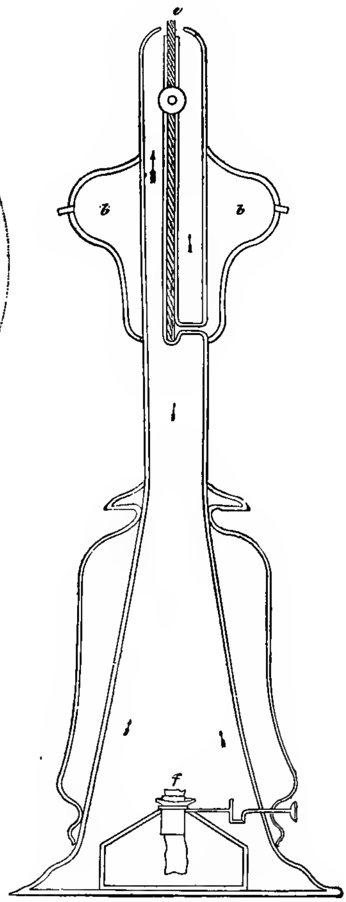


FIG. 194.



was soon improved upon by Argand, who introduced the tubular wick, Fig. 180 (p. 257); this again, has in large measure been replaced by a flat wick of suitable width which readily adjusts itself round the inner wick-tube, and is preferable to an ill-fitting tubular wick. King (Patent No. 2967, A.D. 1859) bifurcates the lower part of the wick, the holder being similarly formed to receive it.

Fig. 196 represents a burner, introduced in 1857 by William Young (Patent No. 1675, A.D. 1857), fitted with two wicks *d*, which are supplied by a single wick *c*. Fig. 191 (p. 262) shows a lamp described in the same specification, and

already referred to, in which the wick is surmounted by a perforated metal annulus *h*, which really forms the wick.

The arrangements employed in these various lamps for adjusting the height of the wick present no particular features of importance. Hero's self-trimming lamp, Fig. 163 (p. 248), has already been described, and

FIG. 195.

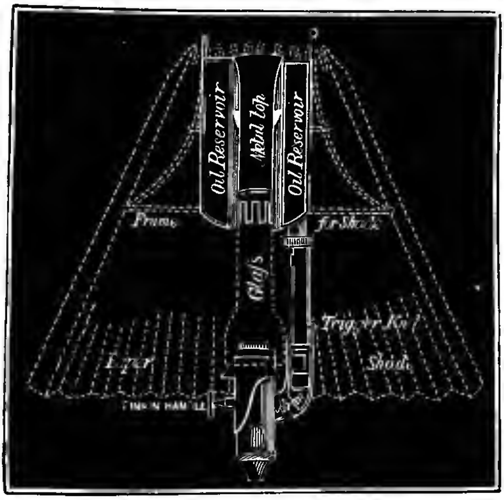
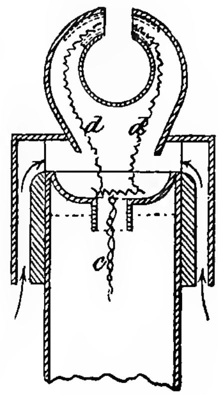


FIG. 196.



certain simple methods of adjustment by hand are shown in other drawings or have been mentioned. In the "Sinumbra" lamp, Fig. 179 (p. 256), the wick is carried by a holder having a short pin working in a spiral groove in an inner cylinder *f*, and another pin working in a straight slot in an outer tube *b* connected with the lamp gallery. The wick is thus raised or lowered on turning the gallery.

CHAPTER II.

The Evolution of the Mineral Oil Lamp.

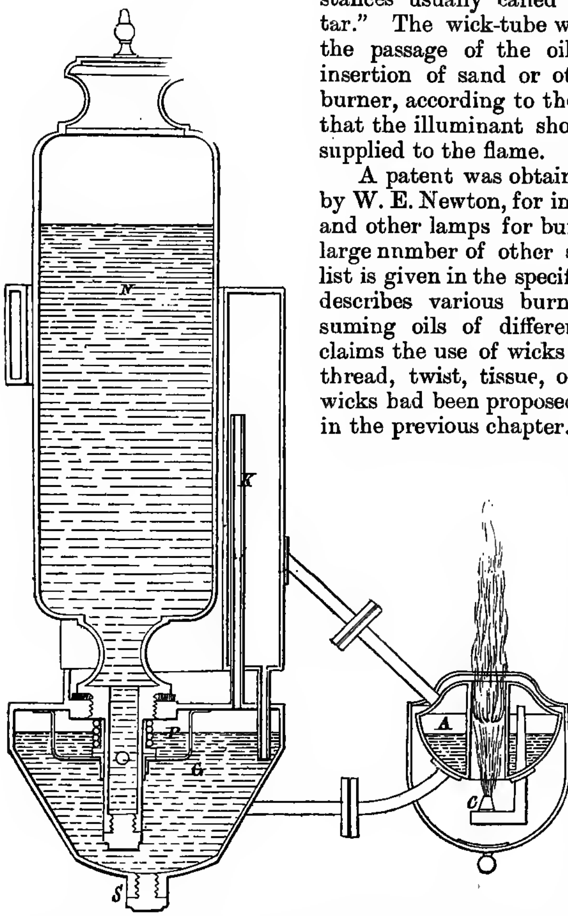
ALTHOUGH the description of lamps for use with fixed oils given in the previous chapter applies generally to the mineral oil lamp and exhibits the earlier stages of its evolution, the latter type of lamp has so many characteristic features and has so completely displaced the former, that a separate chapter may well be devoted to a consideration of its development.

The special features of mineral oil lamps are mainly due to the comparative volatility and inflammability of the various descriptions of mineral oil commonly used for illuminating purposes, as well as to the high percentage of carbon in the oil; these conditions render it necessary to guard against any considerable elevation of the temperature of the bulk of the oil, and especially against the ignition of an inflammable or explosive mixture of petroleum vapour and air which may be formed in the upper part of the lamp reservoir, whilst at the same time the illuminant must be continuously supplied in proper quantities to the flame, and air admitted in such a manner as to produce a brilliant light by the smokeless and odourless combustion of the oil. There are also details of construction peculiar to lamps for burning

mineral oils which are not covered by the foregoing general definition, such as devices for facilitating the lighting and extinguishing of the lamp, as well as arrangements for minimising the risk of ignition of the oil in case of accident to the lamp. These will be exemplified in the following description of typical forms of mineral oil lamps.

As early as 1818, a patent was granted to Sir Thomas Cochrane (Patent No. 4241) for "lamps for streets, which effectuate and regulate the combustion of a certain purified essential oil or spirit obtained from different ligneous, carbonaceous, or bituminous substances usually called spirit of tar or oil of tar." The wick-tube was varied in length, or the passage of the oil was retarded by the insertion of sand or other material into the burner, according to the density of the oil, so that the illuminant should not be too rapidly supplied to the flame.

FIG. 197.



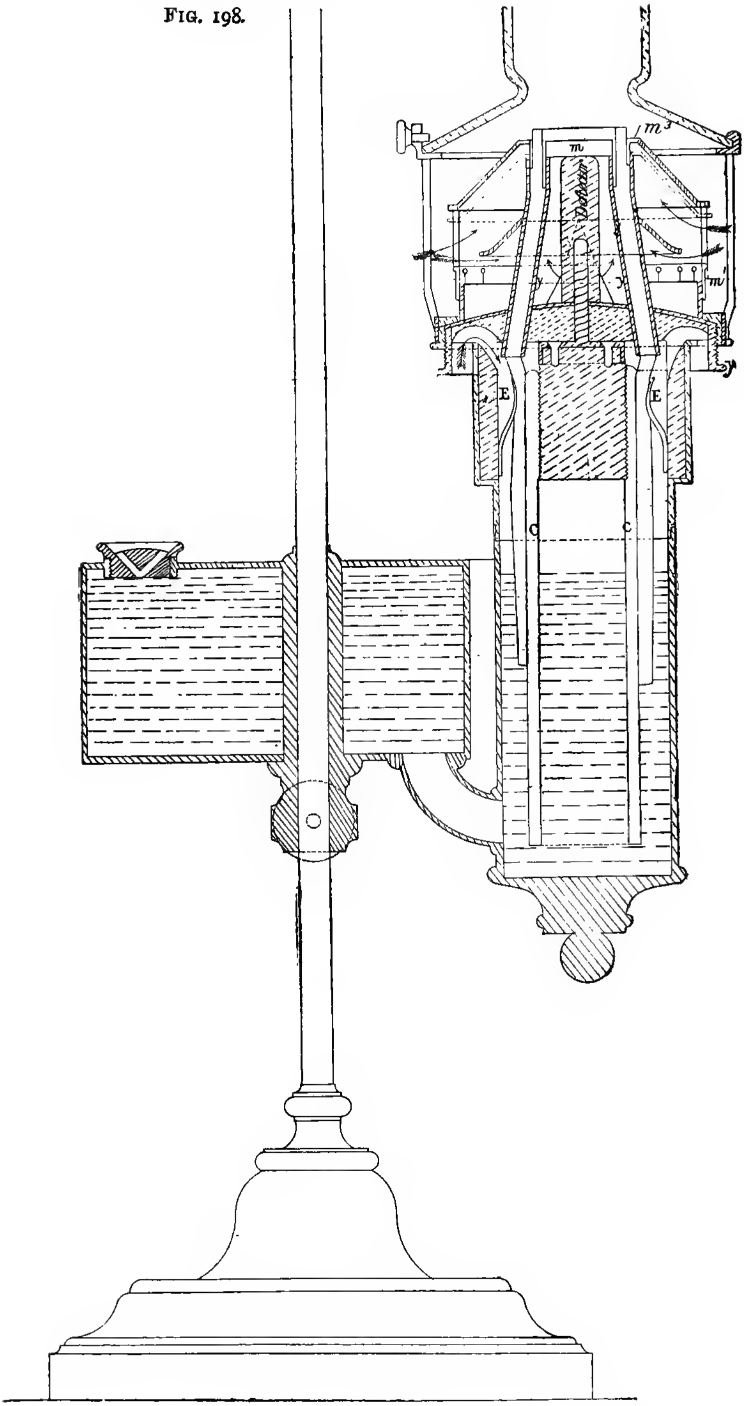
A patent was obtained in 1841 (No. 9195) by W. E. Newton, for improvements in vapour and other lamps for burning petroleum and a large nnmber of other substances, of which a list is given in the specification. The inventor describes various burners suitable for consuming oils of different densities; he also claims the use of wicks of glass in the form of thread, twist, tissue, or gauze, though such wicks bad been proposed long before, as stated in the previous chapter.

Fig. 197 is a section of one of his vapour lamps, in which the heat of the flame volatilises the oil in a chamber *A*, supplied from a receptacle *G* having a supply reservoir *N*. The oil flows from the vessel *G* to the chamber *A* as fast as it is consumed, an air chamber *K* communicating with both admitting air to the vessel *G* as the level falls. The vapour from the chamber *A* passes through the burner tube and burns at a small jet *C* of platinum or other metal.

The first lamps, however, in which mineral oils were burned to any great extent were the so-called "camphine" lamps, previously introduced for use with oil of turpentine.

Fig. 198 shows a lamp introduced in 1842 by William Young (Patent No. 9368. It has a number of flat wicks arranged so as to form a roughly tubular wick, and having the air passing round and between them. They receive the oil through a tubular wick C, against which they are pressed by springs E. Sometimes a single flat wick, bent into a tubular form, is used, the nearly meeting edges being sufficiently distant to permit the

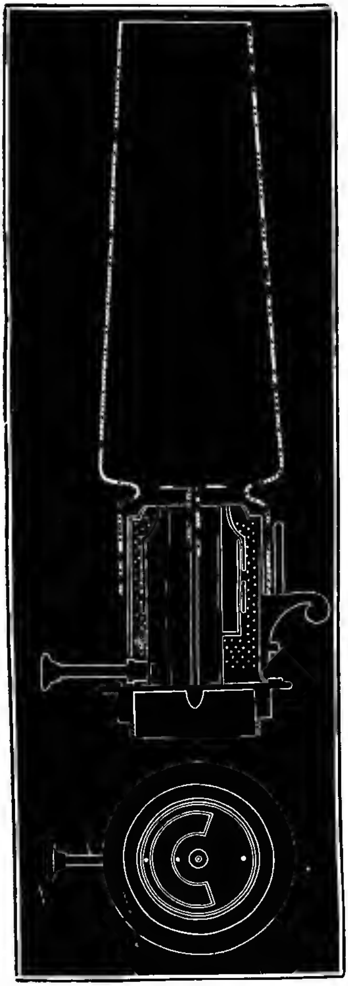
FIG. 198.



passage of air between them. To regulate the amount of surface exposed to the flame, the wicks are surrounded outside by a ring or tube m^3 and inside by a ring or tube m, both carried by a holder m^1 adjustable vertically on the lamp body. Thus the amount of wick exposed to the flame is varied by raising or lowering the holder.

Fig. 199 represents the burner of James Young's well-known "Vesta" lamp, which is of the Argand form with a "Liverpool button" for deflecting the internal current of air, entering near the pinion handle and passing through the burner to the inner side of the flame. The wick-tube is encircled by a cone, the outer current of air entering between the two and impinging on the flame. This lamp was introduced for burning camphine, but was also largely used for burning the oil obtained by distilling shale.

FIG. 199.



In 1842, George Roberts (Patent No. 9446) introduced a lamp, Fig. 200, in which the air is directed upon the flame at different heights by rings or perforated discs, *i*, *j*, *k*, *l*, of regularly decreasing internal diameter, the ring *i* being of somewhat smaller diameter than the flame. The air passes through openings in the frame *e*, and travels up to the rings within a tube *m*.

Fig. 201 shows Roberts's "Gem" lamp, which is said to have been the best camphine lamp of its time. The internal air current passes to the Argand burner through a tube *a*, traversing the reservoir, and is directed on to the flame by a deflector *f*. The external air supply passes through two series of holes in the gallery supporting the chimney.

Several deflectors patented by Roberts in 1845, and depicted in Fig. 183, have already been described.

Prior to the year 1859, the only lamps used in America for burning petroleum were imported from Vienna, but in that year no fewer than forty patents were granted in the United States for petroleum lamps and burners and appliances in connection with them. The number of patents taken out subsequently increased from 71 in the year 1860 to 186 in 1876.

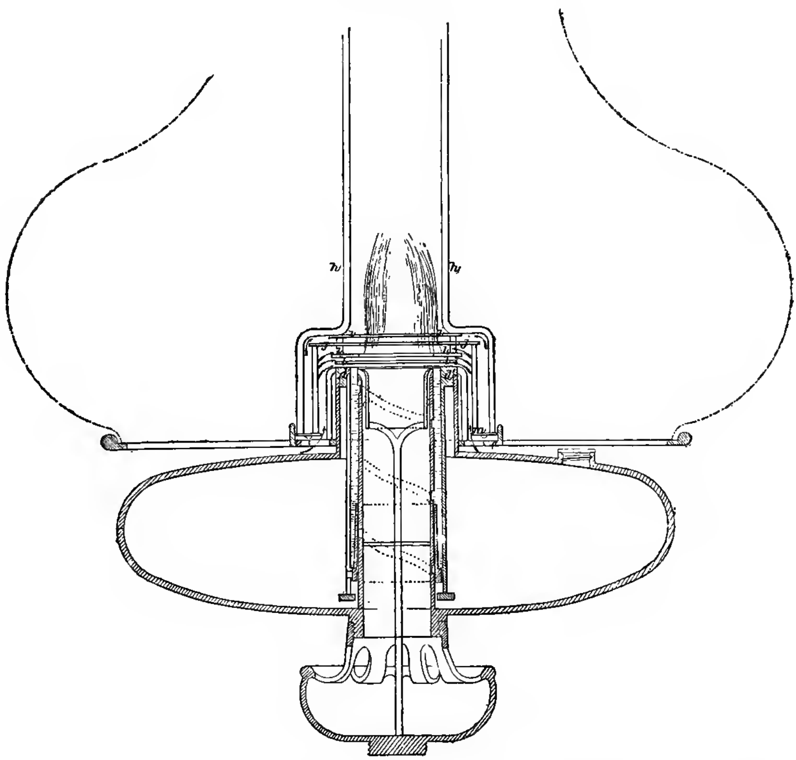
Fig. 202 represents four of the old mineral oil lamps formerly in use in the United States—I. being a spring-catch brass stand-lamp, introduced in 1860; II., a glass stand-lamp, with the Hale burner, which was patented in 1858; III., a screw-catch glass stand-lamp; and IV., a spring-catch lamp.

In 1852 or 1853, Stobwasser, of Berlin, introduced his "Solar Oil Argand Burner," for use with the "photogene" prepared by Noblée, of Hamburg, by distilling coal, as well as a flat-wick burner for the oil obtained from lignite. The latter form of burner was soon adopted, with some modifica-

tions, for burning shale oil, and was largely manufactured by R. Laidlaw and Son for Young's Paraffin Light and Mineral Oil Company.

Meanwhile, in this country the improvement of appliances for burning mineral oils was steadily progressing, and in 1865 J. and J. Hinks obtained a patent (No. 2785) for their well-known duplex burner. This burner, which had been foreshadowed in a two-wick burner constructed by Angus Smith and in William Young's two-wick burner which is shown in Fig. 196, and has been previously mentioned (p. 264), has two or more wicks placed in tubular holders *a b*, Fig. 203 (p. 271), of straight or semi-cylindrical or other curved form, so arranged that the flame shall be of duplex or circular, elliptic, or other form. The air supplied to the inner surface of the flame enters the tube *c* through

FIG. 200.



branch tubes, the open ends of which pass out between the wicks; whilst that supplied to the outside of the flame passes through a perforated plate *m*, into the dome *i*, which is provided with openings *k l* for the passage of the flames. In the present form of the Hinks duplex burner, two flat parallel wick-tubes are employed, and the wicks are not brought together at the base of the burner in the manner exhibited in the figure. A dual burner, having two flat wicks in a cone furnished with a single slot, was patented in 1871 by Holver Holverstone, of Cambridge, Mass. Litigation between this inventor and J. and J. Hinks resulted in an amicable arrangement.

In 1866, T. Rowatt patented (Patent No. 203) his "Anucapnic" burner, Fig. 204 (p. 272), in which two distinct air-currents are produced and directed on to the flame, without the use of the ordinary chimney, by means of two

cones or deflectors *d f*, the outer of which rests on the perforated flange of the inner, air being supplied to the inner cone through apertures *e*, in its support *b*.

Thomas Rowatt and Sons patented an improved "Anucapnic" burner in 1878, and introduced their "Lorne" burner, Fig. 205 (p. 272), in 1882. In the latter, the wick-tubes are inclined, so that the flames coalesce, while the wicks beneath the burner are in contact; increased luminosity in the flames, and increased capillary attraction in the wicks, being claimed for this arrangement.

FIG. 201.

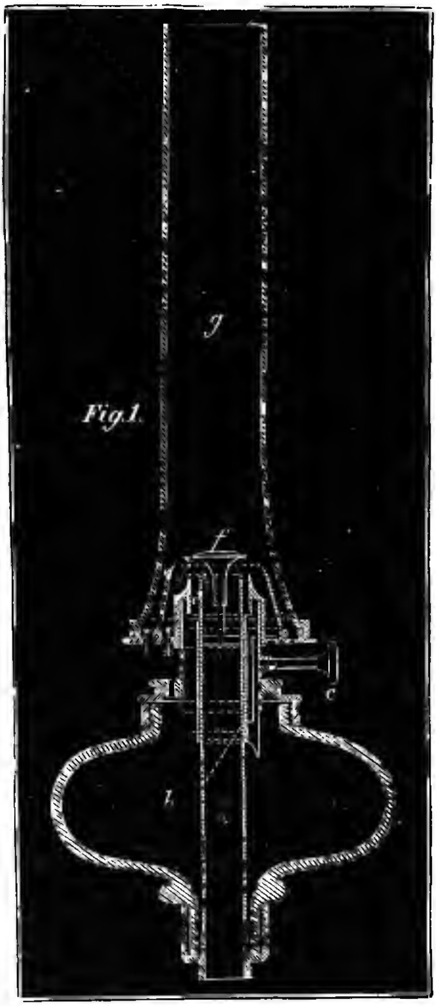


Fig. 206 (p. 272) shows a lamp introduced in 1867, by George Young (Patent No. 525). The air is supplied through perforations *a e*, formed in a casing *E* and a cap *F* respectively. The air supplied at *a* is directed to the upper part of the wick by a cap *c* and a tube *b* carried by it. Sometimes the cap is perforated, and the tube *b* dispensed with.

The lamp illustrated in section in Fig. 207 (p. 273) represents one of a number supplied from a single elevated tank by the system patented by Peter Brash and William Young in 1867 (No. 1315). Each lamp is connected with the tank by a tube, and the oil supply is controlled by a valve, which is closed by the action of a float *F* when sufficient oil has entered the reservoir. Two wicks are used, and the flames coalesce, as in the Lorne burner. The lamp shown is arranged to give a horizontal flame.

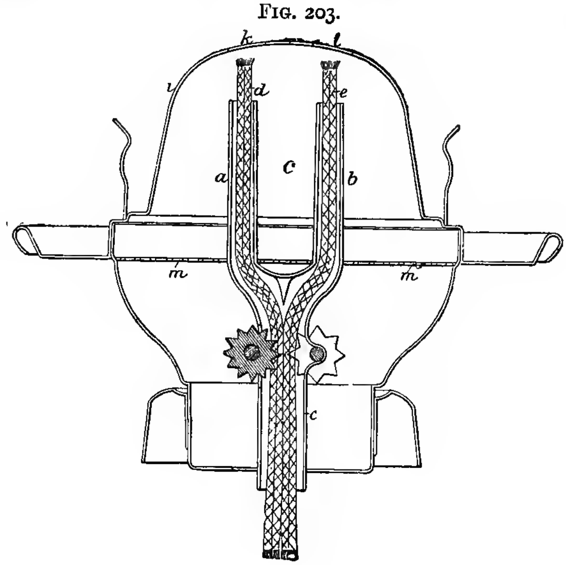
Fig. 208 (p. 274) represents a burner patented in 1870 by John Young (No. 1906), which may be used with the globe shown or with an ordinary chimney. The supply of air to the flame is obtained by the use of a perforated casing 5 and a cone 4, the lower part of which is provided with perforations through which a portion of the air passes into the chimney. The adjustment of the burner tube to the proper distance below the cone 4 is said to be of importance in obtaining the maximum light.

In the burner shown in Fig. 209 (p. 274), which was patented by Silber in 1873 (No. 1304), the air is supplied to the upper part of the tubular wick, which is drawn over a tube *b*, by one or more bell-mouthed or straight concentric tubes *B C*, perforated at *d* for the entrance of air. The usual dome or cap is applied above the burner.

FIG. 202.

I. II. III. IV.

FIG. 203.



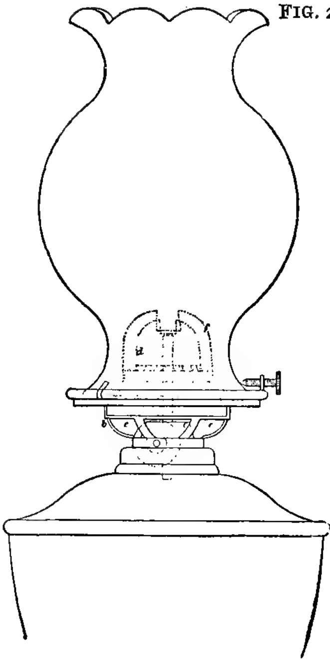


FIG. 204.

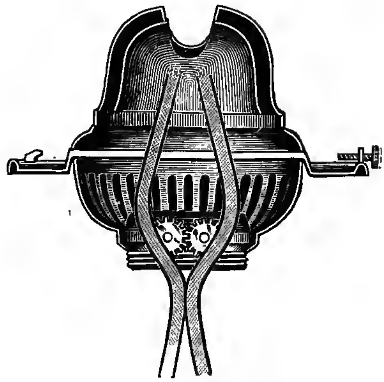


FIG. 205.

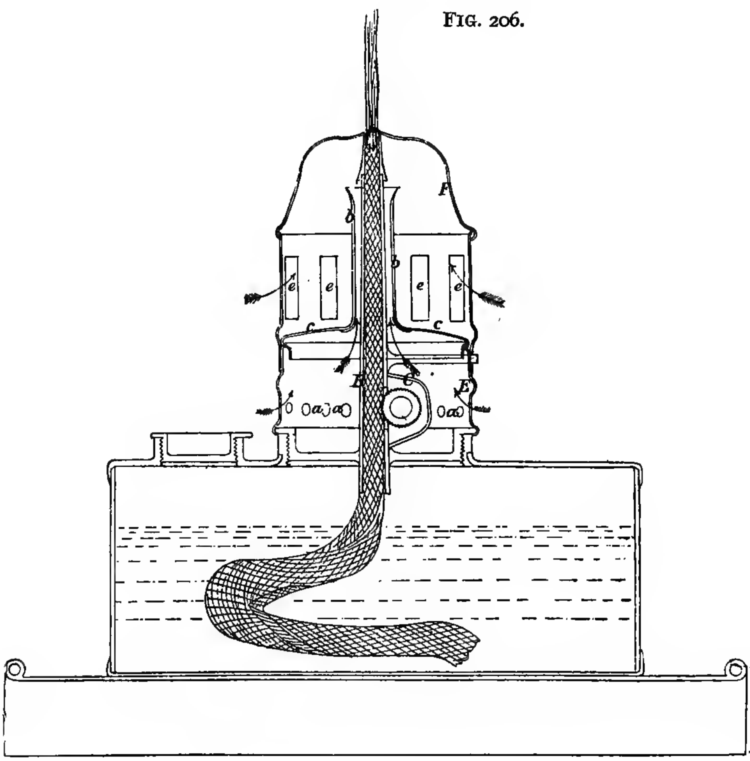
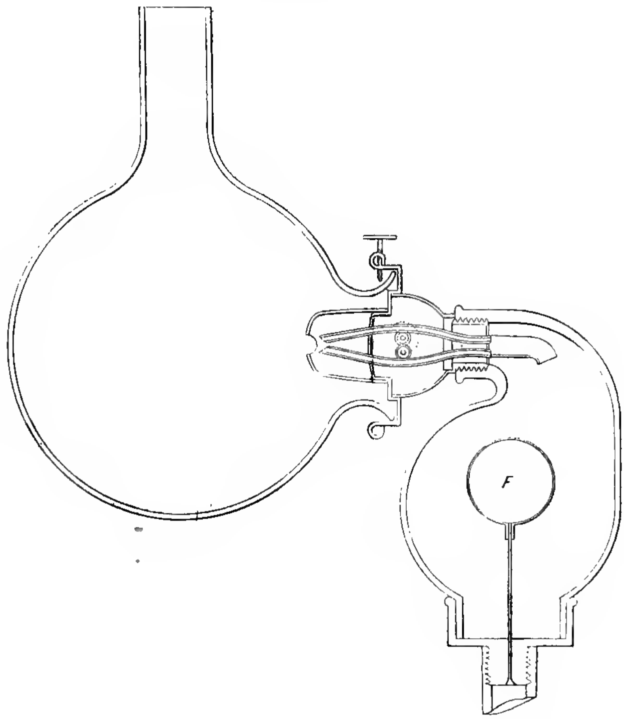


FIG. 206.

Two years previously, Silber patented a lamp provided with an annular air space passing vertically through the body of the lamp between the wick chamber and the oil reservoir. Oil was supplied to the wick through several small tubes connecting the base of the oil reservoir with the wick case, and thus the main body of the oil was kept cool.

The Doty triplex burner, which was patented in England in 1876 through the agency of Morgan-Brown (No. 893) is represented in Figs. 210 and 211 (pp. 274 and 275). This burner is fitted with three flat or curved wicks passed through tubes *d*, which are preferably inclined so as to nearly meet at the top in order to prevent undue enlargement of the neck of the lamp, while ensuring a good supply of air. The wicks are preferably arranged

FIG. 207.



to form a triangular flame. The dome has three intersecting, hemispherical enlargements, with openings for the passage of the flames.

The "Doty triplex," as well as the "Champion" and "Regulator" burners, which were patented by Ragg (Nos. 2220 and 4252, A.D. 1878, and 1007, A.D. 1880), has been largely manufactured by Young's Paraffin Light and Mineral Oil Company.

Figs. 212, 213, and 214 (p. 275) show the original "Champion" burner. It is preferably constructed with two wick holders F, which are flat at the bottom, and gradually shaped to a semi-cylinder at the top, so that the flat wicks are brought together in the form of a cylinder. The holders terminate at the top in a tubular annulus G, through which the wicks pass, and are connected by a perforated plate S. The height of the cap or air deflector A is varied by means of a screw H until the air, which enters through the

FIG. 208.

FIG. 209.

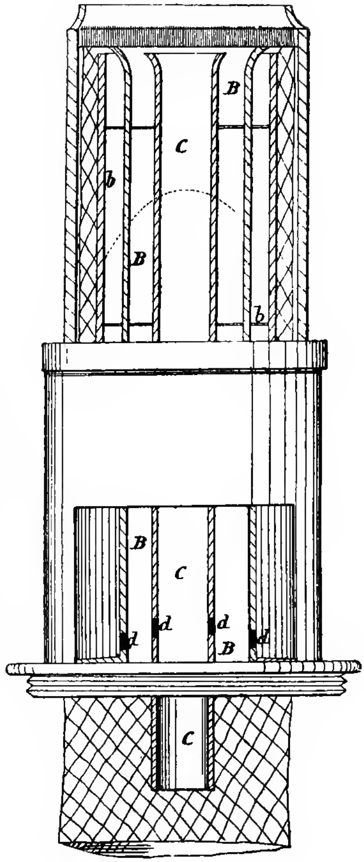
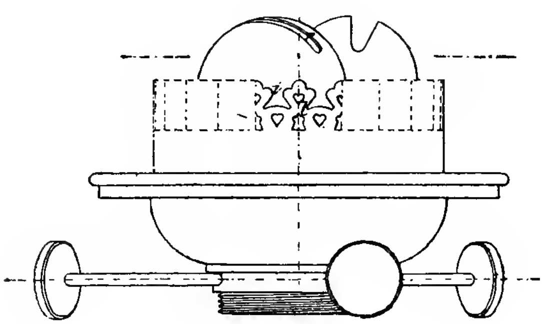
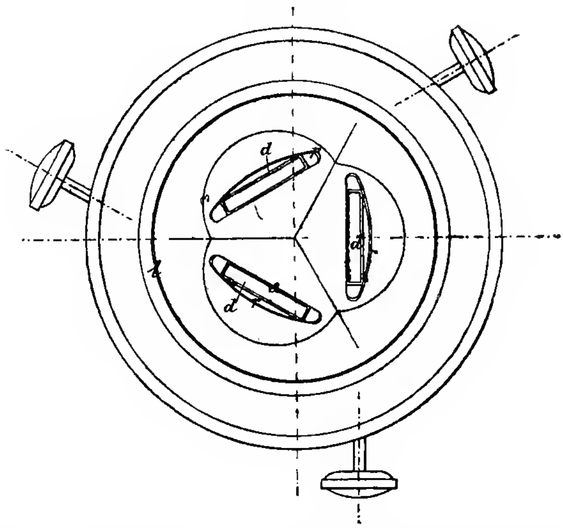


FIG. 210.



perforated casing I, is so directed as to produce a white flame. The air is supplied to the inside of the flame by the perforated cone F, Fig. 214, covered at the top by a cap, or by an arrangement of double cones B C, Fig. 213, closed at each end by a perforated cap. When the single cone F is used, the

FIG. 211



space between it and the flame may be divided by radial arms into a series of channels through which the air is stated to pass to the bottom of the flame, and divide it into a series of smaller flames, whilst the air from

FIG. 212.

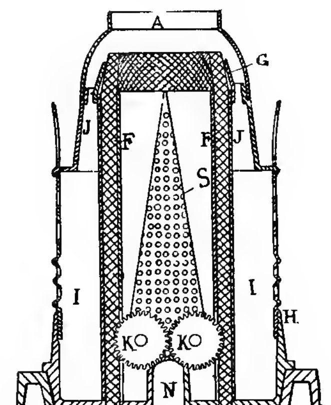


FIG. 213.

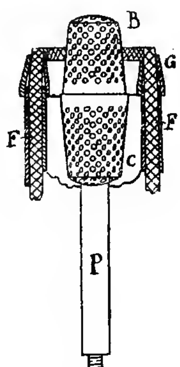
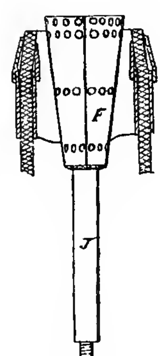


FIG. 214.



the top of the cone impinges upon the higher parts of the flame. In the "Improved Champion" burner, Fig. 215, which is intended for burning the heavier oils, the air is supplied to the flame through the medium of a vertically adjustable air chamber *F*, perforated at its base and open above, and by the use of a very large "Liverpool button" *B*, perforated at its

edge, and carried by a perforated support *M*.* The chimney gallery is fitted with a perforated plate *E*, which directs the air equally round the flame.

Fig. 216 exhibits the construction of the "Regulator," which consists of

FIG. 216.

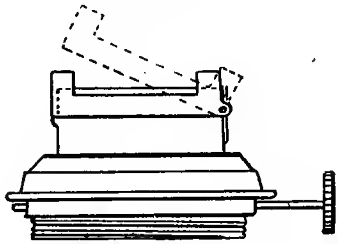


FIG. 215.

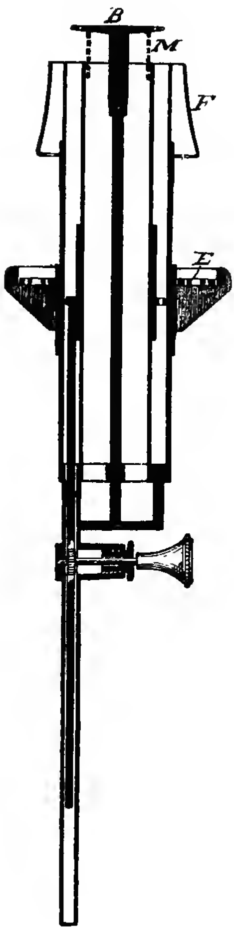
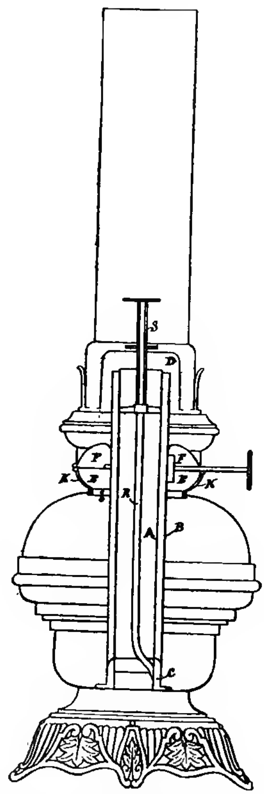


FIG. 217.



a cap attached to the cone, and so formed that it covers up a portion of the wick, and protects it from the action of the flame. The regulator prevents the wick from being raised enough to cause the emission of smoke; it also facilitates trimming, and, when heavy oils are used, acts by covering the corners of the wick, so that such parts form feeders to the burning portion,

* Many other Argand burners described in this chapter may be used with the "Liverpool button."

a plentiful supply of the illuminant being thus secured. For burning heavy oils without a chimney, Ragg fits in the slot in the burner dome a shallow trough with the bottom cut out over the wick. The trough becomes much heated, and produces a broadening of the flame.

In the "Defries Lamp," Fig. 217, patented by Sepulchre (No. 5428, A.D. 1881), the tubular wick passes between two tubes *A B*, the tube *B*, which is grooved to facilitate the passage of the oil, being fixed to the removable burner, and kept concentric with the tube *A* by a short tube *C*, secured thereto. The tube *A* forms a channel for the conveyance of air from the base of the lamp, through the oil reservoir, to the interior of the Argand burner, whilst the tube *B* serves to arrest the passage of flame into the reservoir, and prevents outflow of the oil if the lamp is overturned.

FIG. 218.

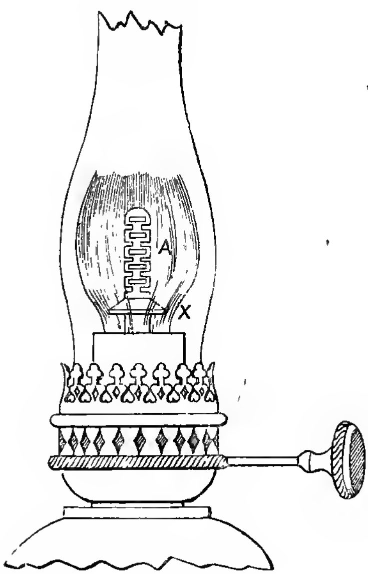
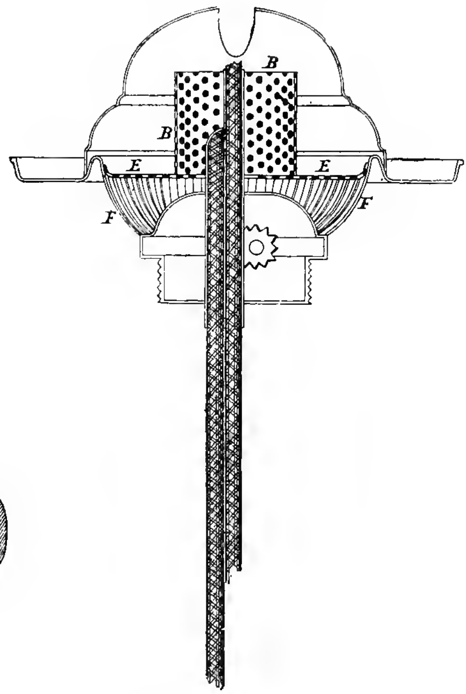


FIG. 219.



The wick-adjusting mechanism is enclosed between concave and convex cups *E F*, the former fitting gas-tight in the funnel *K*, through which the lamp is charged. The air is deflected against the inside of the flame by two discs on a tube *S*, fitted on a wire *R*, and the outside of the flame is supplied with air through the burner cap *D*. Fig. 218 shows an improved form of air-diffuser, *A X*.

The "Lampe Belge," which is made by the Midland Lighting Company, has a central air-tube passing through the oil reservoir, and is furnished with an excellent arrangement for raising and lowering the wick.

Among the chimneyless lamps may be mentioned the "Empire" and "Peerless" burners, patented by Rippingille (No. 668, A.D. 1879, and No. 2048, A.D. 1884), and manufactured by the Albion Lamp Company. These burners differ in details of construction from those previously described, particularly as regards the supply of oil to the flame.

Another chimneyless burner, Fig. 219, is that of Lighbody (Patent No. 117, A.D. 1874). The air passes to the burner through apertures *F*, a perforated plate *E*, and a perforated cylinder *B*; it is thus broken up and uniformly distributed.

In Postlethwaite's "Excelsior Duplex" burner, the wicks are adjusted simultaneously by two pinions geared together, and the two flames, which pass through a single slot in the burner cap, very nearly coalesce, but are separated by a thin stratum of air, which improves the combustion and luminosity. To prevent spreading of the flame at the top, two currents of cold air are admitted directly to the chimney.

Fig. 220 represents the "Excelsior Argand" burner, manufactured by Kiesow and Co. It has two wicks meeting together to form a cylinder, and secured by wire clips to a tube, which is raised or lowered by a rack and

FIG. 220.

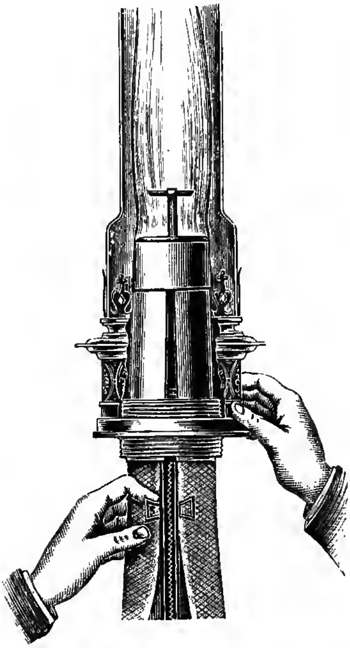
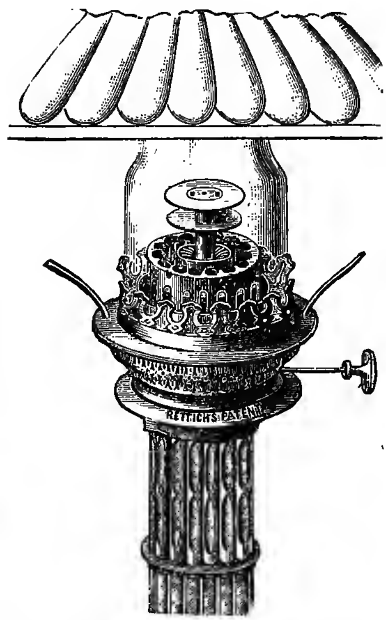


FIG. 221.



pinion. Thus the wick is not touched by the gearing, and may be of very loose texture. The tube also prevents the turning down of the wick to a dangerous extent. A "Liverpool button" distributes the air to the interior of the flame.

The "Mitrailleuse" burner, Fig. 221, patented by Rettich, has a large number of solid cylindrical wicks, which are arranged in a circle, so that they may be adjusted simultaneously by one winder, and cannot be turned down so as to drop into the reservoir. An air-diffuser with two discs aids the combustion as in other lamps, and a small platform is arranged to catch any pieces of charred wick which fall into the burner. This lamp has an arrangement for raising the gallery with the chimney and globe to facilitate lighting.

Fig. 222 shows the "Lampe Veritas" introduced by Falk, Stadelman and Co. It is provided with a specially shaped air-diffuser or button, and with the wick-raising arrangements illustrated.

Sugg's "Westminster" burner is remarkable in being constructed with wick-tubes of steatite.

An American lamp, on the Argand principle, patented in 1882 by J. Funck, has a long inner wick-tube, extending almost to the bottom of the cylinder which serves as an outer wick-case. The wick is held in another long tube of thin metal, to which is attached a stud working in a spiral groove made in a fourth tube extending downwards from the collar which supports the cone. The tube which holds the wick is revolved by a pinion working in teeth cut in the lower edge of the cone, so that through the action of the spiral groove the wick is raised or lowered.

In the American "Rochester" lamp (U.S. Patent No. 348,969, A.D. 1886), an air-diffuser consisting of a cylinder C, Fig. 223, closed at the top

FIG. 222.

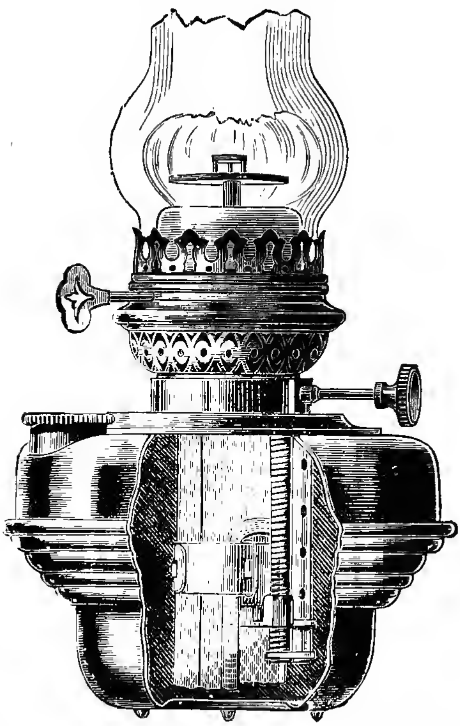
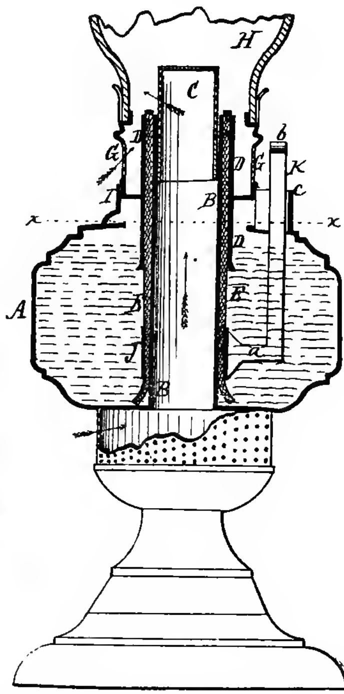


FIG. 223.



and having perforated walls, is used. The wick passes between the air-tube B and a tube D, and is carried by an annulus or hoop J, which is raised or lowered to adjust the wick by means of a rod K, having a handle b and sliding in a split guide c.* The holder J and the connected parts may be lifted entirely from the lamp for the insertion of a new wick.

A recent improvement (U.S. Patent No. 364,438, A.D. 1887) in this lamp, consists in fitting outside the tube B a short tube, the upper end of which forms the air-diffuser C. The use of this tube is stated to prevent the creeping of the oil down the inside of the tube B to the base of the lamp.

In the "Royal Argand" burner, manufactured by the New York Brass Company, there are two wicks, connected by a bayonet catch, one wick

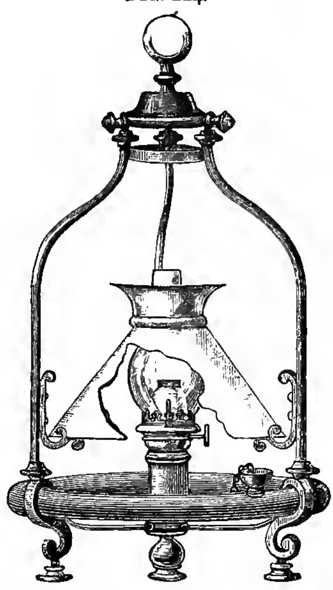
* A flexible wire such as is employed in a dentist's drilling machine has, in another form of lamp, been substituted for the rigid rod K.

supplying the oil to the other, which forms the burner wick The burner is so constructed that the wick cannot be unduly lowered.

The "Waterbury lamp" has an ingenious arrangement for facilitating the insertion of the wick, whilst the "Star" lamp has an annular air-space surrounding the wick-tube and passing through the oil reservoir on the principle of Silber's lamp already described. Both these American lamps have Argand burners, and are fitted with extinguishers.

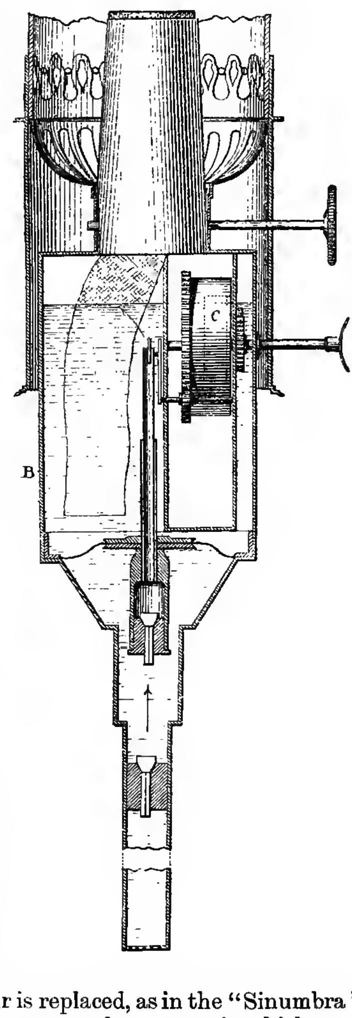
Among American flat-wick burners may be mentioned the "Sun-hinge" and the "Manhattan." In the former the cone can be raised, like the hinged lid of a box, for trimming or lighting without removing the chimney. The latter is fitted with a double cone, and gives a tall,

FIG. 224.



well-shaped flame. The principal features of the American flat-wick burners in comparison with similar English burners, are the thinness of the metal, which is stated to minimise the conduction of heat to the reservoir, and the shortness of the wick-tubes, which is of advantage in diminishing the height to which the oil has to be raised.

FIG. 225.

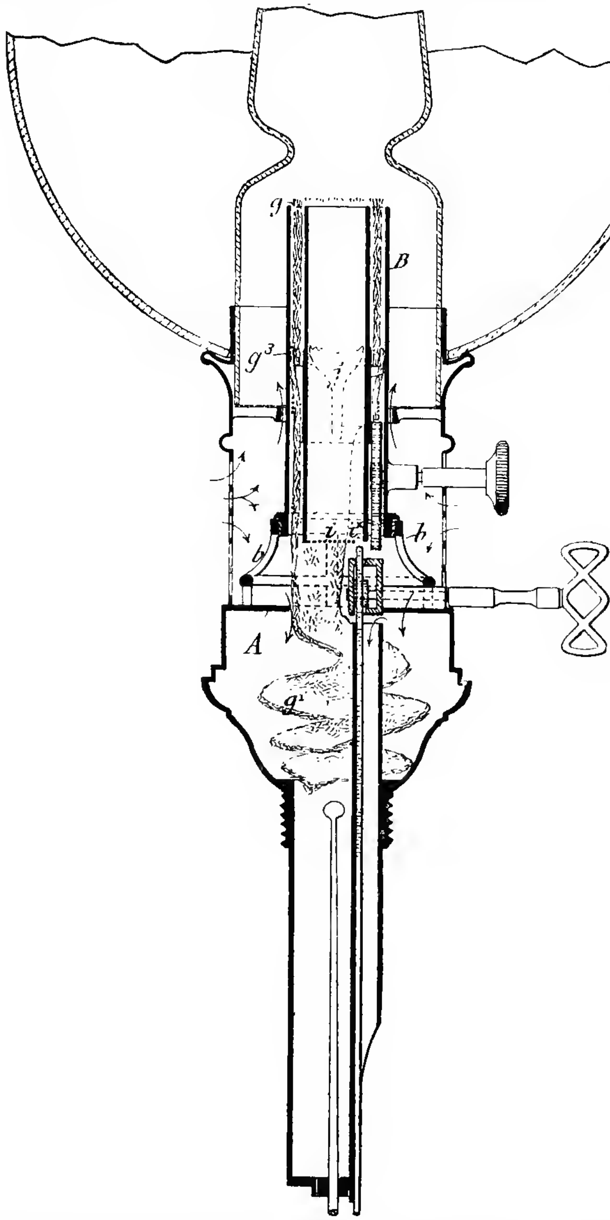


In Fig. 224 is shown "Trotter's shadowless" pendant lamp. The ordinary reservoir is replaced, as in the "Sinumbra" lamp described in the previous chapter, by an annular reservoir which supplies a small central chamber forming the reservoir proper. This chamber is always full of oil, as it is lower than the main reservoir, and there is therefore no risk of the formation of an explosive atmosphere in it.

The "Moderator" and "Carcel" principles previously described as applied to lamps burning fixed oils, have been adapted to petroleum lamps by several inventors. Fig. 225 exhibits the construction of the "Auto-

regulator" lamp of Peigniet-Changeur. The oil is raised from a lower receptacle into a reservoir B, by a pump driven by clockwork C. When the

FIG. 226.



level in the vessel B is sufficiently high to lift a float the mechanism is stopped, and a constant oil-level is thus maintained.

Fig. 226 shows the application of the "Moderator" principle patented

by Aria (No. 16,073, A.D. 1887). The oil is forced by a piston from the main reservoir in the lamp base, into a vessel A, whence it is supplied to the wick. The burner is fitted with a wire gauze disc i, to arrest any falling pieces of charred wick, a skeleton support b, and a perforated casing. The cylindrical wick g is supplied by a wick g^1 secured to it at g^3.

FIG. 227.

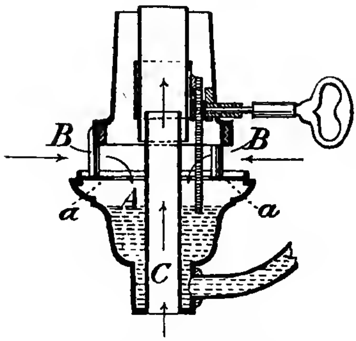
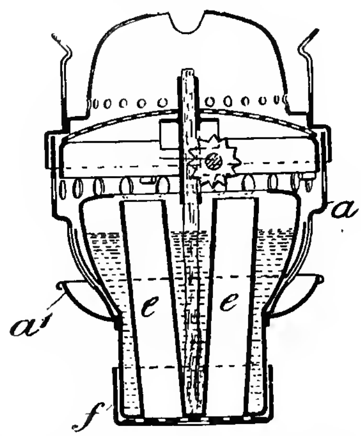
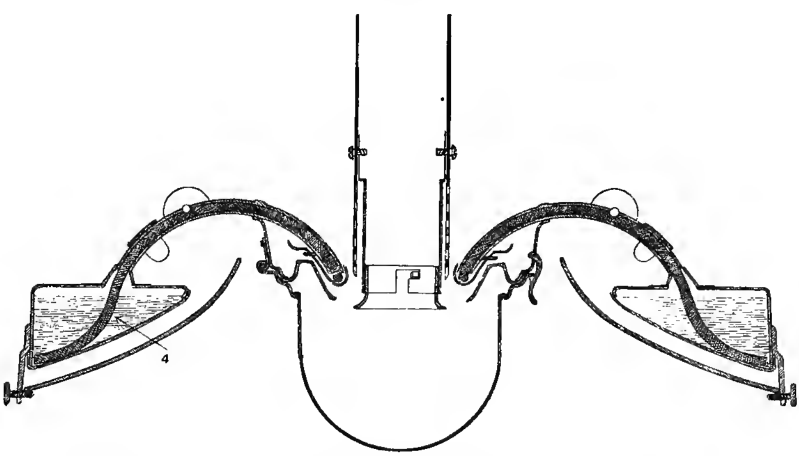


FIG. 228.



In another arrangement invented by Aria (Patent No. 15,768, A.D. 1888), the receptacle A, Fig. 227, which has a flange a to prevent overflow from the shaking of the lamp, is supplied either from an upper reservoir as in a reading or railway roof lamp, or from a lower level by means of a pump or piston as in the Carcel or Moderator lamp. A central tube C supplies

FIG. 229.



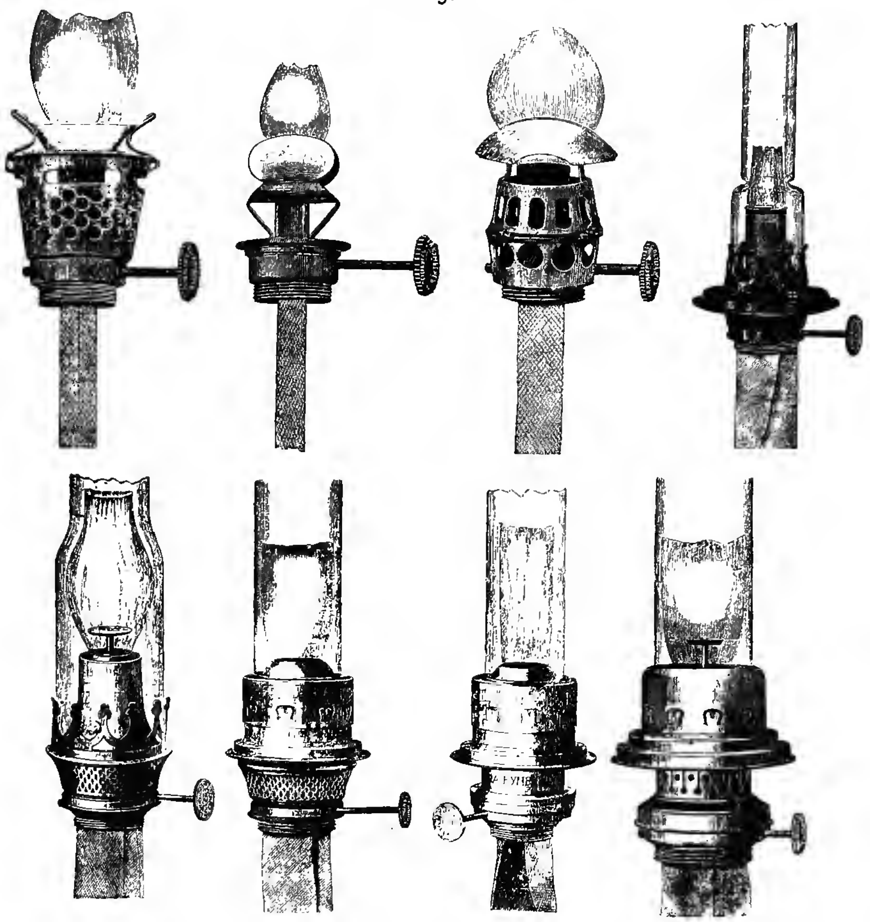
air to the flame, and a skeleton frame B supports the burner above the reservoir. An ordinary tubular wick is used.

In a flat-wick burner, Fig. 228, described in a later specification of Aria (No. 8995, A.D. 1890), the frame B is replaced by a perforated annulus a^* and the tube C by two semi-cylindrical air-tubes e, the lower ends of which are covered by a cap f formed with a slot which may be more or less closed so

as to regulate the admission of air. A cup a' receives any overflow. Two or more wicks placed side by side may be used.

Fig. 229 shows the "Sunlight" lamp of Ross and Atkins (Patent No. 2019, A.D. 1889). It is a mineral oil lamp working on the inverted Argand principle, so successfully applied to gas-burners. The burner wick preferably consists of an annulus of the ordinary loosely woven spirit lamp wick, but may be formed of "solid permeable material made of asbestos fibre or of porous mineral." It is supplied by three flat wicks 4,

FIG. 230.



or by a number of separate round wicks, from an annular reservoir fitted with a reflector to increase the light. Sometimes the ends of the wicks, 4, themselves constitute the burner, in which case they are arranged to form a circle at that point. A cone deflects the air to the flame, whilst a cylinder of porcelain, so placed as to become strongly heated, raises the temperature of the air which is supplied to the flame through the perforated chimney. A burner cap limits the outward movement of the wick. The arrangement of the lamp is such that the flame curves inwards instead of outwards, so that the wick does not become unduly heated.

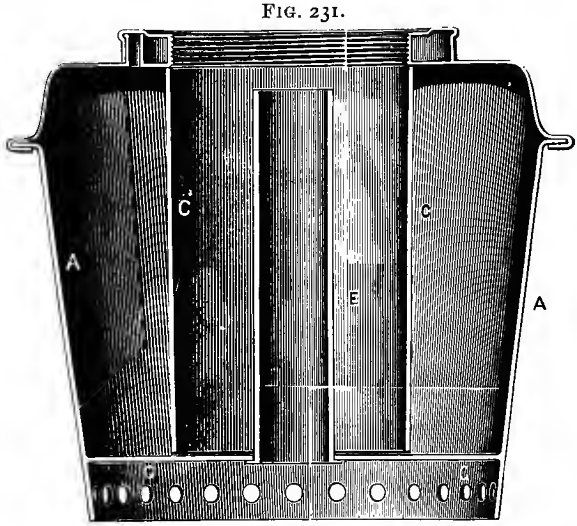
Hampton and Sons have recently introduced a lamp under the name of "The Perpetual Lamp," which is designed to obviate the necessity for frequent replenishing with oil. The base of the lamp forms a receptacle for a week's or month's supply, and is surmounted by a glass oil-container which is refilled when necessary by a concealed force-pump.

Joseph Hinks and Son have recently exhibited a new form of pedestal lamp with a capacious reservoir at the base, from which the oil is automatically raised in successive quantities to a small oil chamber immediately below the burner by the intermittent action of an ingeniously contrived piece of mechanism driven by a spring.

Both in this country and in America, flat-wick burners have until within the last few years been far more largely used than Argand or round burners, while on the European continent flat-wick burners are rarely employed.

The commonest form of German round burner is that which is known as the "Cosmos." It has neither the additional inner air-tube nor the

FIG. 231.



button, and accordingly it is necessary to use with it a chimney much constricted a short distance from the base. Better results, especially with the larger sizes, are obtained with the new Argand burners supplied by C. H. Stobwasser and Co., Wild and Wessel, and Schuster and Baer, under the names of the "Victoria," the "Phœnix," the "Moon," and the "Helios."

Fig. 230 exhibits the forms of several Russian burners manufactured by Kumberg. It will be noted that three of these are to be used without a chimney.

Figs. 231 and 232 show the Chandor lamp (Raffalovich's Patent No. 6253, A.D. 1885) for use with heavy Russian oils. Attached to the collar of the reservoir, A, Fig. 231, is a cylinder, or tube of large diameter C, open at both ends and extending nearly to the bottom of the reservoir. Within this is the central air-tube E passing through the bottom of the reservoir. The burner D, Fig. 232, is of the Argand central-draught type.

For indicating the oil-level in a lamp reservoir, Waters (Patent No. 781, A.D. 1889) has introduced several arrangements, one of which is shown in Fig. 233. When the reservoir is filled to the proper height, a float d^1 rises, and a bead d^2, supported on a stem, is brought into view. In another

arrangement an indicator tablet, carried by a pivoted arm attached to a float, is brought opposite an opening when the reservoir is sufficiently full. The inventor also suggests that the float may be secured to a band passing round a drum and carrying the tablet, or that the band may pass round a drum which, through the medium of toothed gear, turns a disc marked "full" and "empty."

Fig. 232.

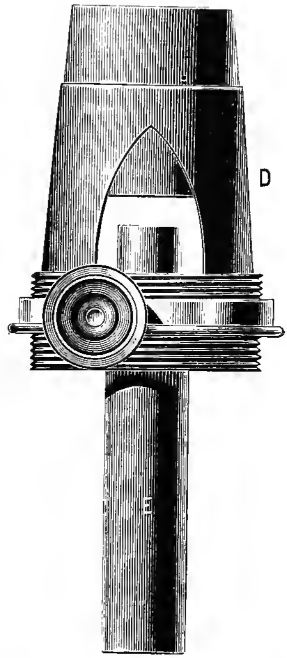


Fig. 234 shows Stobwasser's arrangement for preventing the exterior of the oil reservoir from becoming soiled with the oil. A layer *m* of a compound resembling a mixture of gelatin and glycerin is inserted between the collar *k* and the plaster *g* which is employed to attach the collar to the reservoir. The compound is impervious to the oil and arrests any which may have penetrated the plaster. The oil which passes along the wick-winder *s* drips from a star-shaped wheel *t* upon the conical surface of the collar, whence it returns to the reservoir through the small opening *o*.

Addendum.

Lamps in which a solid or semi-solid product of petroleum or shale oil forms the illuminant are not included in the heading of this chapter, but may be appropriately referred to here.

Young's Paraffin Light and Mineral Oil Company have introduced a convenient lamp for use by miners which is charged with solid paraffin of low melting

Fig. 233.

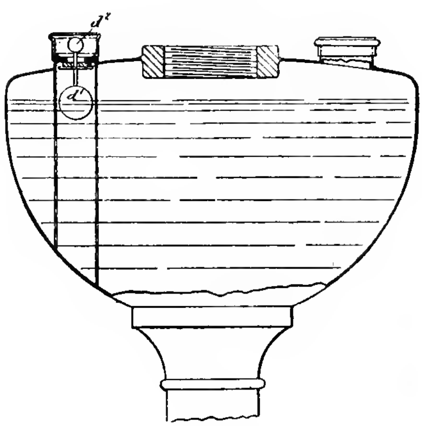
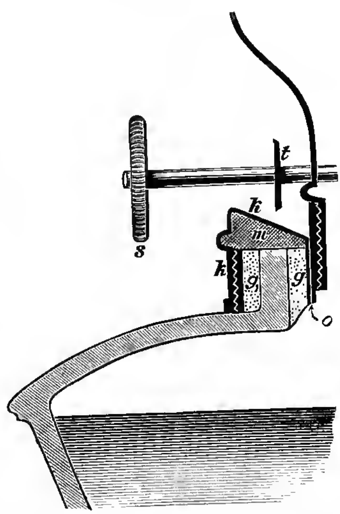


Fig. 234.



point. The lamp is in the form of a little tin can with a projecting spout which forms the wick-tube. No chimney is employed and the flame

is encircled by a ring of copper wire which conducts heat to the paraffin in contact with the wick and maintains it in a state of fusion.

The Cera Light Company, Limited, have devoted considerable attention to the employment of paraffin of low melting point as an illuminant, and now manufacture ships' signal lamps for burning this material. The burner with which these lamps are fitted is furnished with an air deflecting cone in lieu of a chimney, and the heat necessary to maintain the paraffin in a fluid condition is conveyed to the reservoir by means of a copper wire which is bent into a helical form just above the flame of the lamp, passes vertically downwards by the side of the wick-tube, and terminates in the reservoir in a coil of such dimensions as the circumstances under which the lamp is to be used may render desirable. The paraffin used has a melting point of 40° C. (104° F.).

CHAPTER III.

The Principles of Construction of Mineral Oil Lamps; Lamp Accidents; Prolonged Wick Tube and Safety Cage for prevention of Explosions.

Much attention has been directed of recent years to the subject of lamp accidents and to the construction of lamps in which mineral oils may be safely burned. In 1871, Dr. Chandler of New York published the results of a series of experiments chiefly directed to ascertaining the relation between the flashing point of the oil and the temperature to which it was liable to be raised in the reservoirs of various lamps in use at that time.

These experiments are of interest in relation to the occurrence of explosions due to the ignition of a mixture of air and petroleum vapour in the lamp reservoir, but, as has been pointed out by Peckham in his Census Report, as well as by Abel in a lecture delivered in 1875 at the Royal Institution, a large proportion of lamp accidents are due to the overturning or dropping of the lamp, and not primarily to an explosion.

The subject of mineral oil lamp accidents was experimentally investigated by Sir Frederick Abel in association with the writer, and with the assistance of Dr. Kellner, and certain definite conclusions were arrived at with respect to the immediate causes of lamp explosions. The results were given by Sir Frederick Abel in a lecture at the Royal Institution in 1885, and were subsequently embodied in a report presented to Her Majesty's Chief Inspector of Explosives in 1890 by Sir Frederick Abel and the writer, on the causes of lamp accidents and the principles of construction which should be adopted with a view of preventing such accidents.

The following is an extract from the report:—

(*a*) A large proportion of the accidents occurring in the use of mineral oil lamps are not due to the occurrence of explosions in the lamps. Many recorded instances of the breaking out of a fire, or the destruction of or injury to life, which are ascribed to lamp explosions have evidently been caused by upsetting or dropping a burning petroleum lamp. The sudden cooling of a glass reservoir which has become much heated by the burning of the lamp may also result in fracture. The substitution of benzoline (mineral spirit) for mineral oil has in some cases probably caused the accident.

(*b*) There are, however, numerous cases of accidents which have undoubtedly been due to the occurrence of explosions in lamps, and our experiments have enabled us to arrive at the following conclusions with respect to the causes of such explosions.

If the lamp be so carried or rapidly moved as to agitate the oil, a mixture of vapour and air may make its escape from the lamp in close proximity to the flame, and, by becoming ignited, determine the explosion of the mixture existing in the reservoir. This escape may occur through the wick-tube itself if the wick does not fit the holder properly, or through openings, of sufficient size to allow flame to pass them readily, which exist near the wick-tube in many burners. Some lamps have a tube inserted in the burner, through which the reservoir can be supplied with oil, and if this tube be not effectively closed it may constitute a channel for the passage of flame to the vapour-and-air mixture in the reservoir. The existence of an imperfectly closed filling aperture in the body or reservoir of the lamp also favours the occurrence of an explosion. A sudden cooling of the lamp, resulting from its exposure to a draught, may give rise to an inrush of air, thereby increasing the explosive character of the mixture of vapour with a little air already contained in the reservoir, and the flame of the lamp may at the same time be drawn or forced into the air space filled with that mixture, especially if the flame has been much reduced in size by lowering the wick, as the point of combustion is thereby brought nearer to the reservoir.

If the practice is resorted to of blowing down the chimney with a view to extinguish the lamp, the effects already indicated as producible by exposure to a draught may be brought about. If the wick be lowered very much, or if for some other reason the flame becomes much reduced in size, so that it is burning beneath the dome, the lamp may become much heated, and its susceptibility to the effects described will be increased. Heating of the lamp-reservoir is likely to be promoted if the air-passages in the burner are obstructed by dirt or charred wick. If the wick is not long enough to reach the bottom of the oil reservoir, and the lamp is allowed to burn until the surface of the oil is scarcely level with the end of the wick, a proper supply being therefore no longer furnished to the flame, the wick may char down to and below the level of the toothed wheels in the wick-tube and drop into the reservoir while the upper end is still burning, and may thus cause an explosion. The accidental dropping of the still burning wick into the oil reservoir, through the wick being turned down below the level of the toothed wheels in the act of extinguishing the lamp, is also a fruitful source of explosions. If the flashing point of the oil used be below the minimum (73° Abel test) fixed by law, and even if it be about that point, or a little above it, vapour will be given off comparatively freely, but the mixture of petroleum-vapour and air formed in the upper part of the reservoir of the lamp will probably be feebly explosive in consequence of the presence of an excess of the vapour. On the other hand, if the flashing point of the oil be comparatively high the vapour will be less readily or copiously produced, and the mixture of vapour and air may be more violently explosive, because the proportion of the former to the latter is likely to be lower, and nearer that demanded for the production of a powerfully explosive mixture. If the quantity of oil in the lamp reservoir be but small, and the air-space consequently large, the ignition of an explosive mixture produced within the lamp will obviously exert more violent effects than if there be only space for a small quantity of vapour and air, because of the lamp being comparatively full.

Experiments have demonstrated that the burning of an oil of comparatively high flashing point is more likely to cause heating of the lamp than the use of an oil of comparatively low flashing point, in consequence of the higher temperature developed by the former, and of the greater difficulty with which some oils of that description are conveyed to the flame by the wick. It therefore follows that safety in the use of mineral oil lamps is not

to be secured simply by the employment of oils of comparatively high flashing point (or low volatility), and that the use of such oils may even in certain cases give rise to dangers which are small, if not entirely absent, with oils of comparatively low flashing point.

The character of the wick materially affects not only the illuminating power of the lamp but also its safety. A loosely-plaited wick of long staple cotton draws up the oil freely and regularly, even when the supply of the liquid in the reservoir becomes almost exhausted, and little charring of the wick takes place if the oil is of good quality. But if the wick be tightly plaited, or if it be made of short staple cotton of inferior capillary power, the oil will be less copiously supplied to the flame, and considerable charring of the wick, with largely increased heating of the burner, will ensue. The use of a wick which has not been thoroughly dried before immersion in the oil, or the capillary power of which has become impaired by prolonged use, may bring about the same result.

Our experiments have also led us to the conclusion that a lamp explosion is not usually sufficiently violent to cause the fracture of an ordinary glass reservoir, although in several recorded cases it has had this effect; but although it may not, the alarm created by the explosion may lead to the lamp being dropped if it is being carried at the time, and if the reservoir is of glass, fracture will probably ensue and the liberated oil may become ignited.

The following suggestions as to the construction and management of mineral oil lamps, founded on recommendations made by Sir Frederick Abel and the writer, were formulated and published by the Metropolitan Board of Works in 1885.

1. That portion of the wick which is in the oil reservoir should be enclosed in a tube of thin sheet metal, open at the bottom; or in a cylinder of fine wire gauze, such as is used in miners' safety lamps (28 meshes to one inch).

2. The oil reservoir should be of metal, rather than of china or glass.

3. The oil reservoir should have no feeding-place or opening other than the opening into which the upper part of the lamp is screwed.

4. Every lamp should have a proper extinguishing apparatus.

5. Every lamp should have a broad and heavy base.

6. Wicks should be soft, and not tightly plaited

7. Wicks should be dried at the fire before being put into lamps.

8. Wicks should be only just long enough to reach the bottom of the oil reservoir.

9. Wicks should be so wide that they quite fill the wick-holder without having to be squeezed into it.

10. Wicks should be soaked with oil before being lit.

11. The reservoir should be quite filled with oil every time before using the lamp.

12. The lamp should be kept thoroughly clean, all oil should be carefully wiped off, and all charred wick and dirt removed before lighting.

13. When the lamp is lit the wick should be at first turned down, and then slowly raised.

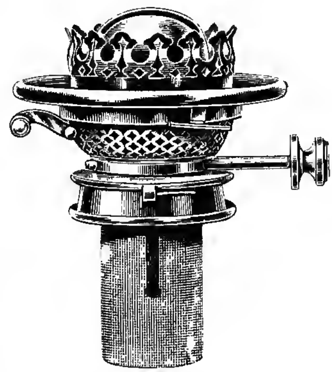
14. Lamps which have no extinguishing apparatus should be put out as follows:—The wick should be turned down until there is only a small flickering flame, and a sharp puff of breath should then be sent *across* the top of the chimney, *but not down it.*

15. Cans or bottles used for oil should be free from water and dirt, and should be kept thoroughly closed.

In a lecture delivered in 1888, before the Prussian Industrial Society, on experiments made by the German Standards Commission, Dr. Fock

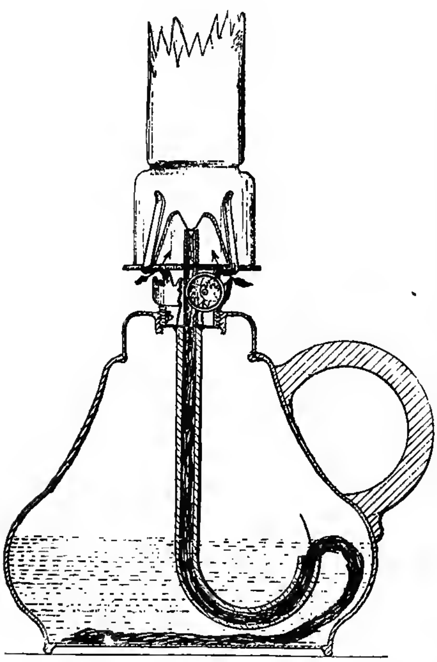
stated that the pressure resulting from the explosion of a mixture of petroleum vapour and air in a *closed* vessel might be as high as fourteen atmospheres (210 lbs. per square inch), the most violent explosions apparently occurring at about 8° C. (14.4° F.) above the flashing point of the oil. The results of the experiments led him, however, to the conclusion that the risk of fracture of the oil reservoir by explosion was very small, owing to the pressure being relieved through the wick-tube, even a cracked reservoir withstanding the pressure. He attributed the cracking of glass reservoirs to the heating of the wick-holder from the ignition of the vapour driven off by the heating of the oil, and recommended the use of metallic or other unbreakable reservoirs.

FIG. 235.



The actual amount of light obtained by the combustion of the same quantity of oil in different lamps varies considerably, Argand burners almost invariably giving more light than flat-wick burners. Thus the minimum consumption of oil per candle-light per hour in the case of flat-wick burners is ordinarily about 50 grains as compared with about 41 grains in the case of Argand burners.

FIG. 236.



As the result of an extended series of photometric experiments made by the writer, in conjunction with Mr. T. Horne Redwood in 1879, it was found that with the principal forms of lamps then in use, the consumption of oil ranged from about 45 grains to 65 grains per candle-light per hour, whilst a series of not strictly comparable experiments made more recently with the assistance of Mr. Robert Redwood, exhibit a range from about 41 grains to over 70 grains.

The diminution of luminosity noticed during the use of lamps, may be due to the bad quality of the oil, or to the use of an inferior wick or to a reservoir in which the depression of the level of the oil becomes too great for the capillary power of the wick, but may also be due to the imperfect construction or defective condition of the burner.

To prevent the communication of flame to an inflammable or explosive mixture of petroleum vapour and air in the oil reservoir the writer has suggested the employment of a wire gauze cage or cylinder enclosing the wick, Fig. 235. This arrangement has been applied to the "Duplex" lamps of Hinks and Son.

A similar purpose is intended to be served by the prolonged wick-tube in the lamps of Defries, Fig. 217 (p. 276), Walsh, Fig. 236 (Patent No. 6858, A.D. 1885), Crowley (Patent No. 7271, A.D. 1887), Sherring, Fig. 237 (Patent No. 4997, A.D. 1887), and Johnson (Patent No. 6610, A.D. 1887).

In Walsh's lamp, Fig. 236, the wick-tube may be straight or curved at the end as shown, whilst in Johnson's lamp the bent portion is prolonged nearly to the top of the reservoir. Crowley's wick-tube is made in two telescoping pieces, and thus admits of adjustment according to the depth of the reservoir. It is closed at the bottom, and has a small opening near the lower end for admitting oil to the wick.

In Sherring's "Victoria Safety Lamp," Fig. 237, the air passes to the

FIG. 237.

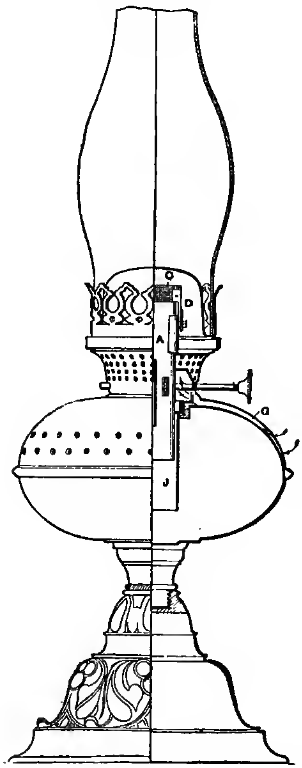
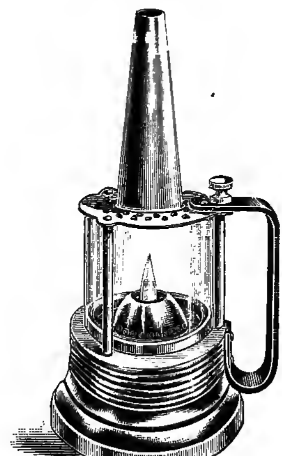


FIG. 238.



burner partly through an air-space G, formed over the top of the reservoir, and the burner is attached to a tube J, which is designed to prevent outflow of the oil in the event of the lamp being overturned.

In the Defries "Artisan" lamp, the wick is enclosed in a tube surrounded by porous material.

In the "Protector Safety" lamp, Fig. 238, introduced by the Protector Lamp and Lighting Company, a permanent wick supplies the oil to a piece of cotton-wool forming the burner proper, which is renewed when it becomes charred. When lighted and put together, this lamp is automatically locked, and the flame cannot be exposed, for on opening the lamp by unscrewing the base, the burning wick is drawn through a sheath, and the flame is extinguished. The flame is protected by a glass cylinder as shown in the illustration.

CHAPTER IV.

Air Supply; the Production, Regulation and Direction of the Air-Currents.—Chimneys, clockwork-driven Fan, secondary Lamp, independent Air Supply.—Domes and Air-diffusers.

THE supply of air in regulated quantity and its proper distribution to the flame, though a very important feature of lamps for use with fixed oils, require still more attention in the case of mineral oil lamps, on account of the higher volatility of the illuminant, and of the larger percentage of carbon present in it, which increases the tendency to the production of smoke.

The arrangements adopted for furnishing the flame with air in the former class of lamps have been fully described in the first chapter, whilst those which are peculiar to mineral oil lamps have been largely dealt with in Chapter II. (p. 265 *et seq.*). Reference should therefore be made to those chapters for further information in relation to many of the arrangements touched upon below.

Although the use of chimneys had been previously proposed by Quinquet, the advantages derivable from the proper supply of air to the flame do not appear to have been distinctly recognised before the introduction of the Argand burner in 1784. In this burner, a tubular wick was substituted for the solid cylindrical wick previously employed, and an interior as well as exterior current of air was directed upon the flame.

This invention was followed by improvements in the form of the chimney; by the introduction of the "Liverpool button," and many other devices for deflecting and distributing the central air-current of an Argand burner so as to bring it into contact with the inner surface of the flame; and by the employment of various forms of domes suitable for use with flat-flame burners. The object of these improvements was the production of a steady smokeless flame of enhanced luminosity.

Although most lamps depend for their supply of air solely on the current induced by the heated chimney, various other arrangements for furnishing the necessary draught have from time to time been suggested. Thus an air-current has been produced by the use of a clockwork-driven fan or a secondary lamp inserted in the base of the lamp, or the action of the chimney has been intensified by the introduction of a blast. In other instances, the burner has been supplied with air under pressure from an independent source.

The chimney originally employed by Argand was of iron. This was soon replaced by a cylinder of glass, which was afterwards contracted or shouldered with the view of causing the air-current to impinge upon the flame. This important improvement has been variously attributed to Lange and to Smethurst (Patent No. 2652, A.D. 1802), although shouldered chimneys are shown in illustrations of lamps used in France during the period of the Revolution.

Chimneys with two constrictions have also been employed, and a telescopic chimney was used by Samuel Highley in his Optical Lantern Lamp.

Fig. 239 represents various forms of glass chimneys now in use. Chimneys of mica, which withstand sudden changes of temperature, whilst almost equalling glass in transparency, are also made.

For the Bayle chimney, Fig. 240 (p. 293), which consists of a cylinder C, surmounted by two truncated cones A B, B C, meeting at their smaller ends, it

Fig. 239.

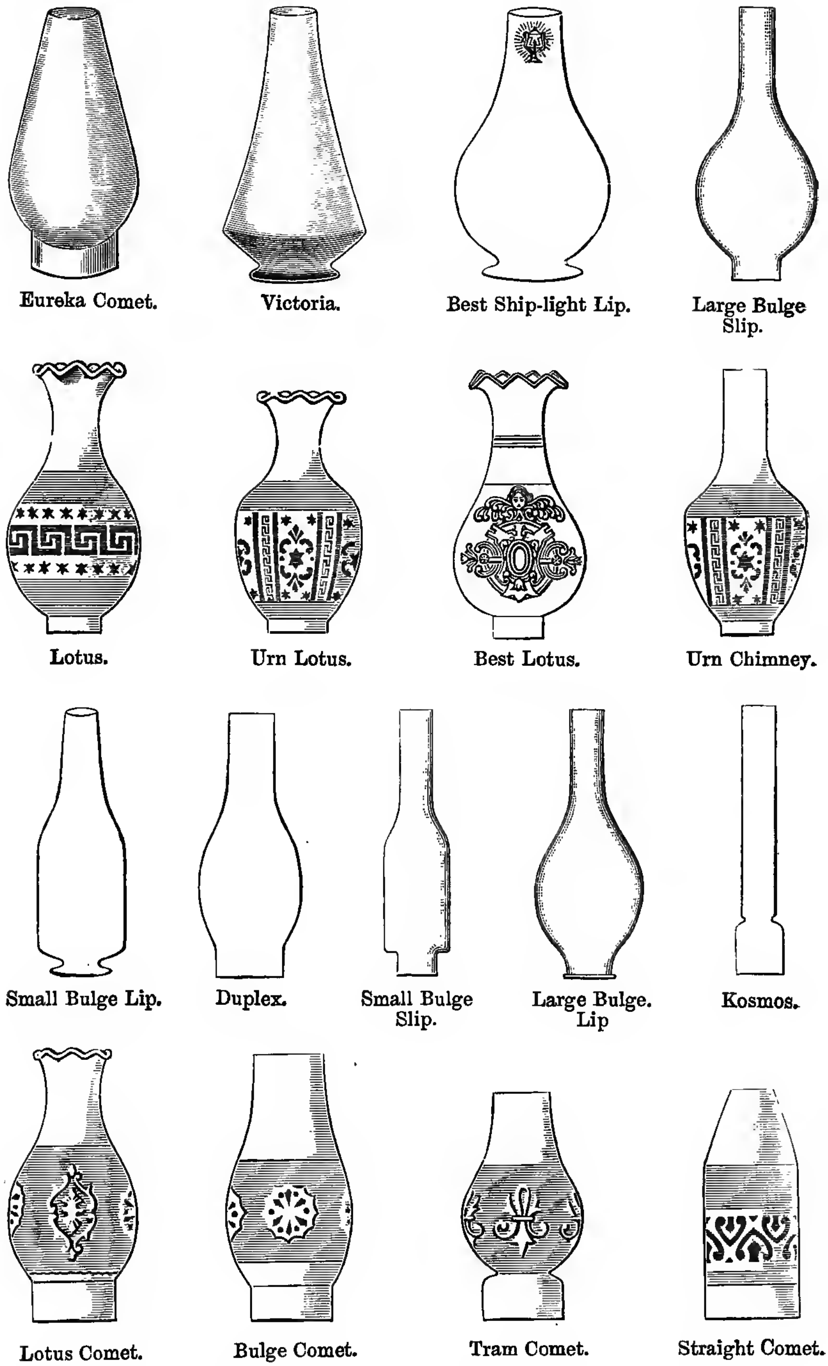
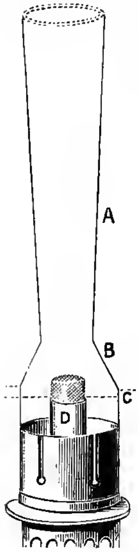
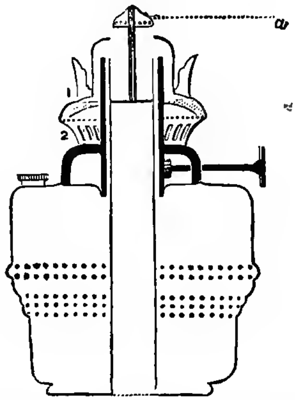

Eureka Comet.
Victoria.
Best Ship-light Lip.
Large Bulge Slip.
Lotus.
Urn Lotus.
Best Lotus.
Urn Chimney.
Small Bulge Lip.
Duplex.
Small Bulge Slip.
Large Bulge. Lip
Kosmos.
Lotus Comet.
Bulge Comet.
Tram Comet.
Straight Comet.

FIG. 240.



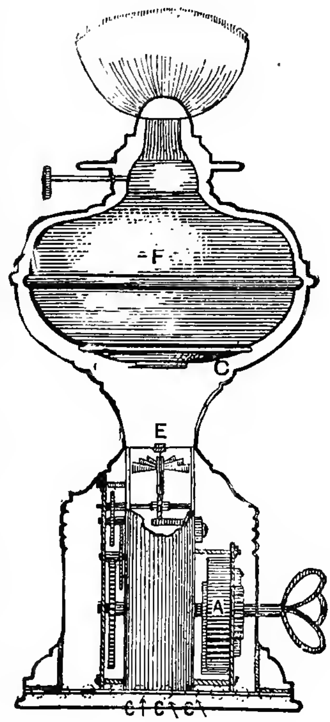
is claimed that the outer air-current entering between the glass and the wick-tube of an Argand burner, is caused to pass upwards with the same velocity as that of the air supplied to the interior of the flame.

FIG. 241.



Among the many previously described air-diffusers and burner-domes, which have been introduced for supplementing the action of the chimney, attention may be again directed to the inventions of Thomas Young, Fig. 171 ; Roberts, Figs. 182, 183, 200, and 201 ; and Hinks, Fig. 203 ; together with the Champion burner of Ragg, Figs. 212 to 215 ; the Doty triplex burner, Figs. 210 and 211 ; the Silber burner, Fig. 209 ; the Defries (Sepulchre) burner, Figs. 217 and 218 ; the Rochester burner, Fig. 223 ; and the burner of the Lampe "Veritas," Fig. 222 ; whilst in the case of the Anucapnic and Lorne burners of Rowatt and Sons, Figs. 204 and 205, the double domes may be regarded as substitutes for the ordinary chimney.

FIG. 242.



The deflector patented by Sir James Douglass in 1881, and largely employed in lighthouse lamps, consists of a triple cone, so arranged as to direct the air upon the flame at three different heights.

In the "Liègeoise" lamp, Fig. 241, the outer air-current passes through a grating 2 in the chimney gallery, and through a gauze disc 1, while the inner air-current is distributed by a deflector *a*.

In the chimneyless "Wanzer" lamp, Fig. 242, the air-current is created by a fan E, driven by clockwork A, and passes to the burner through the space C between the reservoir F and the outer casing.

A clockwork-driven fan is also similarly employed in the "Hitchcock" lamp, formerly known as the "Empress."

The supplying of air or oxygen to the flame by the use of a fan or blower, driven by clockwork or otherwise, or from a reservoir, had, however, been proposed as early as 1840 by Halpin (Patent No. 8689).

FIG. 243.

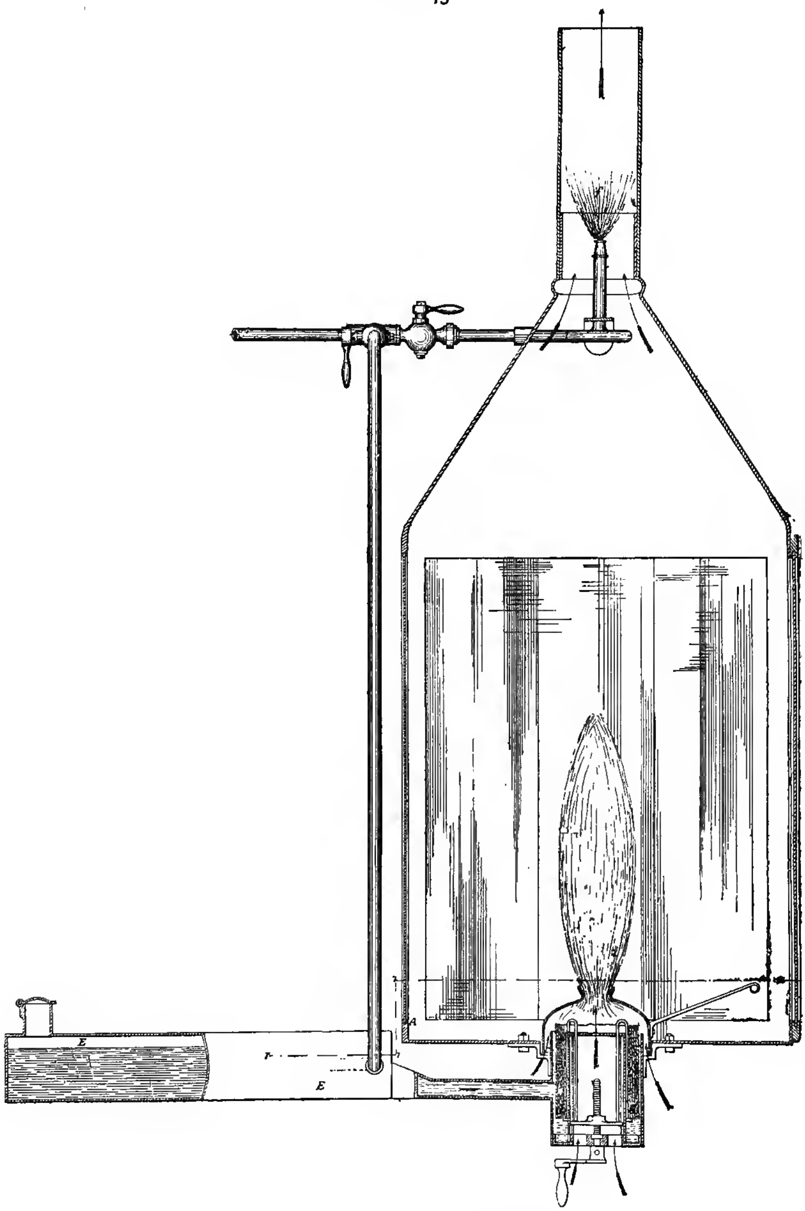


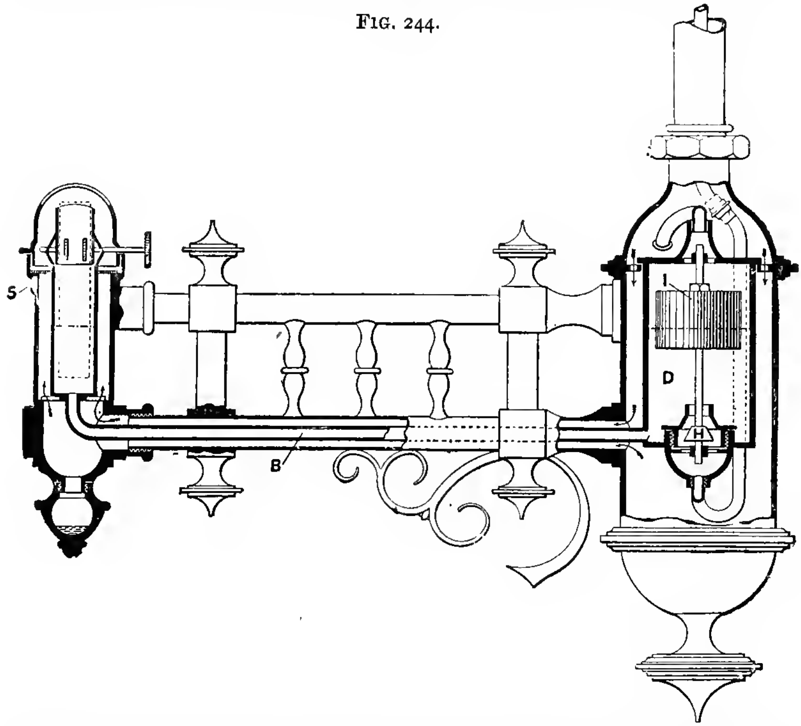
Fig. 243 shows an arrangement patented by Lavender (No. 3797, A.D. 1875) for creating the necessary draught in a lamp or lantern by a jet of steam *f*, or of compressed air. In the lamp shown, which was obviously

intended for use with heavy oils, a branch from the steam pipe passes through the reservoir *E* to warm the oil.

An ingenious arrangement proposed by Rae in 1861 for producing an air-current by the use of a small supplementary flame at the base of the lamp, is represented in Fig. 194, and has been previously described (p. 261).

In the Ross lighting system, Fig. 244, patented by Ross and Nolan in 1885 (No. 2022), no chimney is used, the satisfactory combustion of the oil being effected and steadiness of the flame attained by the use of an

FIG. 244.



independent supply of air under pressure. The burner is fed with oil from a reservoir D, which is automatically replenished from a tank serving for the whole of the lamps in a system. The supply of oil is regulated by a float I, which closes the valve H when the reservoir is charged. The air supply travels round the reservoir D and the oil tube B, as shown by the arrows, and passes through a gauze ring S, which distributes it regularly to the flame.

CHAPTER V.

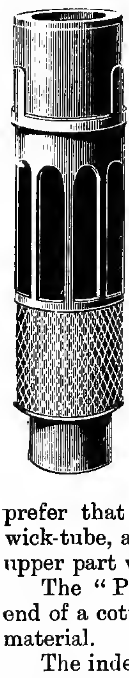
Lamp Wicks, their Manufacture.—Incombustible Wicks.—Arrangements for raising the Wick.

THE earlier history of lamp-wicks of cotton or other material, has been given in Chapter I. (p. 243), whilst numerous methods of arranging the wicks, and means for raising them, have been described in that and the succeeding chapters.

Dittmar and several others have employed a short burner-wick supplied with oil by another wick which passes into the reservoir. This arrangement is specially applicable when the upper wick is of some incombustible material.

The capillary attraction exerted by the wick is largely dependent on its quality, a wick of long staple cotton loosely woven giving far better results than one of short staple cotton tightly woven. Thus, wicks of the same width in ordinary use have, when tested by the writer, been found to differ in the proportion of 198 to 76 in respect to the quantity of oil which they are capable of raising under similar conditions. The capillary power of the wick is considerably impaired by the presence of moisture in the cotton, and as wicks are found to absorb water from the atmosphere to the extent of from 4 to 6 per cent. of their weight, it follows that they should be carefully dried immediately before they are placed in the oil. There appears to be reason to believe that the "choking" of a wick, which occasionally occurs during prolonged use, may, at any rate in some cases, be due to the deposition of water in it, for Nakamura has found that a choked wick recovers its capillary power on drying.

FIG. 245.



Several descriptions of incombustible wicks have been introduced. As already mentioned, the wicks of the lamps employed by the Vestal Virgins are said to have consisted of asbestos, whilst wicks of asbestos or of gold, silver, iron, or other metal in the form of wire were proposed as early as 1684 by Plot (*vide* Chapter I., p. 263). Wicks of platinum, gold, silver, or copper drawn into fine threads, or of glass drawn into capillary tubes and bound into a compact bundle, were patented in 1822 by A. and D. Gordon (Patent No. 4638), and the use of cane or porous wood or asbestos in 1845 by Roberts (Patent No. 10,842).

The wick patented in 1876 and 1877 by Heinrichs, Fig. 245, consisted of a lower portion of felt, an intermediate portion of mineral substance, and an asbestos tip or ring forming the burner.

In the specification of an asbestos wick patented by Flatau and Turner (No. 12,146, A.D. 1884), one claim of the inventors is for the division of the wick into two portions, one of which can be moved up or down so as to be put into or out of contact with the other portion. The inventors appear to prefer that the upper part of the asbestos wick should be a fixture in the wick-tube, and that the lower part should be moved out of contact with the upper part when it is desired to extinguish the lamp.

The "Phœnix Perpetual" lamp wick is prepared by treating the upper end of a cotton wick for a distance of about an inch with an incombustible material.

The indestructible wick patented by Webb (Patent No. 13,324, A.D. 1885) is composed of a mixture of asbestos, silver sand, red-lead, and borax, with a portion of powdered pumice if desired. The mixture is ground to a paste, dried, moulded and baked at a red-heat. These wicks may be used alone, or may be fastened to an ordinary cotton wick which forms the feeder.

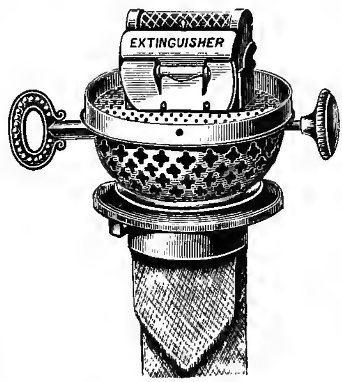
In a patent taken out by Varley and Gooch (No. 3865, A.D. 1888), and based on the above, the burning surface of the wick is proposed to be increased by means of perforations, saw-cuts, &c., and the wicks are described as thickened at the base so as to be more readily fixed fluid-tight in the burner by removable washers and collars. The refractory nature of the wick is stated to admit of the lamp being used on the regenerative principle. The size of the flame is varied by the use of a sliding sleeve or collar over

the end of the wick. Instead of using the above mixture, the wicks may be made of porous clay, or of a mixture of clay and magnesia or rottenstone rendered refractory, or of natural porous stone, such as sandstone or pumice.

Under a patent of Gooch, Varley and Lidstone (No. 5214, A.D. 1888), a mixture of finely powdered sand, asbestos, borax, and red-lead in stated proportions is heated to dull redness to effect a partial fusion, again powdered, and then heated to bright redness in a mould. Clay, rottenstone, and emery or corundum may be used with or instead of the sand or asbestos, and glass or other flux may replace the borax and lead oxides. Another patent by the same inventors (No. 5413, A.D. 1888), includes special forms of holders for these wicks.

Bondini and Tubini have patented (No. 10,502, A.D. 1887) a description of incombustible wick in which the end or tip of an ordinary cotton wick is protected by enveloping it in a capsule or sheath of wire gauze or perforated sheet metal. Sometimes a compound wick formed of thin wicks separated by strips of sheet metal is employed, and sometimes the "burner" portion of the wick consists of asbestos which partially fills the sheath and upon which the cotton wick, which passes into the reservoir, abuts.

FIG. 246.



In Phillips' "Shaftesbury indicating" wick, the upper portion has an inscription printed upon it, and the wick is intended to be replaced by a fresh one when the printed portion is consumed.

In the "Aladdin" burner, Fig. 246, an endless wick turned on the jack-towel principle by a suitable arrangement, is employed, the flame burning on the surface of the fold, so that the necessity for trimming is obviated.*

In ordinary lamps, the wick is raised or lowered by the action of toothed wheels pressing lightly against it, the revolution of the wheels being effected by turning a milled head or button on a spindle carrying them. In some instances, however, the wick is held in a tube or frame which is raised or lowered by a rack and pinion or by a worm cut on the burner tube and actuated by revolving the burner, or, as in the "Rochester" lamp described in Chapter II. (p. 279), by means of a vertical rod attached to the wick frame. As already mentioned, the rigid rod has, in another form of lamp, been replaced by a flexible spiral wire, such as is employed in a dentist's drilling machine.

Manufacture of Wicks.—Considerable attention has for some years been paid in the United States to the construction of wicks, and the writer has inspected the process of manufacture at a factory in Troy. The various

* An Argand-burner lamp has recently been introduced under the name of the "Million Lamp," in which the combustion of the oil takes place from the inner surface of the tubular wick and not as usual from its upper edge The outer wick-tube of the burner of this lamp is provided with a ring or rim at the top, so that the whole of the exterior of the wick and also its upper edge is completely protected from the flame, as in trimming the lamp the wick is drawn tightly against this rim. Within the wick is another closely fitting tube to which a vertical movement is imparted by a lever or key working in an inclined slot, and by means of this tube the extent of the inner surface of the wick exposed can be regulated, and the size of the flame adjusted. The tube can also by means of the lever be raised until its upper end comes into contact with the projecting rim of the burner tube already referred to; the wick is then entirely enclosed between the inner and outer tubes, and the lamp is extinguished. The burner is so constructed that no outflow of oil occurs when the lamp is overturned or even when it is completely inverted. The lamp is furnished with an oil reservoir of metal.

operations in the order in which the cotton is subjected to them are termed:—(1) opening; (2) lapping; (3) carding; (4) railway drawing; (5) doubling and first drawing; (6) doubling and second drawing; (7) slubbing and roving; (8) speeder-roving; (9) spinning; and (10) twisting, to make the yarns ready for the looms.

Mr. Herbert Morgan, of the firm of Joseph Morgan and Son, of Manchester, who manufacture mineral oil lamp wicks more largely than any other firm in this country, has supplied the writer with the following particulars of the various processes through which the cotton is passed.

"The raw cotton employed in the construction of a wick should be a good quality of American, carefully selected and of long staple. The length of the staple forms a very important feature, as this to a large extent governs its capillary attraction. The cotton should be spun into what is known as coarse counts, because it can be easily understood that a fine thread cannot draw the oil with anything like the same power that a coarse loose thread can. When spinning, great care must also be taken to see that only sufficient twist is put into the yarn to enable it to pass through the succeeding processes, as all twist over and above this necessary quantity will be detrimental to its burning power. Here, again, the benefit of the long staple is at once evident. A short-staple cotton must require extra twist to give it sufficient strength to make up for its deficiency in staple, whereas the long staple cotton will have the required strength with the minimum of twist. After we have got the raw cotton into the single yarn, it must be doubled into its requisite number of folds, two, three, or more ends as the case may be, and here again great care is required in the doubling process to prevent undue twist, for the same rule applies exactly in this process as in the spinning process. If more twist is put into the yarn in its doubled state than is required to pass it through the weaving process which immediately follows, this excess of twist will injure the quality.

"We have now got the cotton into the doubled state ready for being made into warp, and here we will more fully explain the component parts of a wick, so that their technical terms may be clearly understood. There are two recognised ways of manufacturing a wick; the easier one of the two, and the one generally adopted, is to make a wick of only three distinct parts. First of all the 'warp,' which means the coarse threads running perpendicularly through the wick and seen distinctly on the outside. Next the very fine threads of cotton passing through the centre of the wick, which work from top to bottom and bind the two surfaces of the wick together. If the wick were woven without these 'binders,' it would be simply a circular wick and not flat. Next we come to the 'weft,' which is the fine cross-threads in the wick, seen on the surface, passing under and over the warp, holding the warp-threads and binders in their proper position, and this completes the construction of an ordinary wick.

"The second mode of manufacturing a wick is exactly as already stated, but with one addition, and this we take to be a most important part of a really good wick. In addition to the binders, which we have said before pass through the centre of the wick and hold the top and bottom together, are placed what are known as 'gut' threads. These threads run perfectly straight through the centre of the wick in the same direction as the warp-threads, but are not crossed or interfered with in any way, either by the weft or the binder. They can be drawn out from the wick without any perceptible difference being made in its external appearance, showing that although they form part of the wick, they are totally distinct and independent of it. In the 'duplex' size, which is perhaps the one most universally known, the number of gut ends should be twelve. We claim for these gut threads that, as they pass direct from the oil to the flame without any

impediment whatever, they must prove a most important auxiliary to the capillarity of the wick and materially assist its burning power.

"The weft employed in wick-making should also receive careful attention, and be made from a good quality of single cotton, two or more fold; hard twisted yarn, such as is often employed, being highly detrimental to the free flow of the oil. The weft is easily seen, as already indicated, on the surface of the wick as it crosses the warp-threads, and the number of these cross-threads per inch should not exceed thirteen, except in the case of very broad wicks, although in some samples we have seen sixteen, and even more are put in, but these are unnecessary and only retard the flow of oil to the flame. In constructing a wick, it is only necessary to make it of sufficient firmness to wind properly, and when you have got the required resisting power to the rack, all over that is detrimental, and not one pick of weft over the number which is absolutely necessary should be inserted.

"But to return to the warping process. This there is nothing special about, as the cotton has simply to be put together in warp of the required number of ends, to make the width of wick wanted. The warp, when made, is taken to the loom and woven into wick. After the wick leaves the loom, a most important process should take place, as on this depends, to a very large extent, whether you will reap the full benefit of the care already bestowed on the wick in its manufacture. We refer to the boiling process. It will be seen that in the number of processes through which the cotton is compelled to pass from its raw state until it appears as a woven wick, there must of necessity pass into it a considerable amount of impurity. This it is quite impossible to avoid, seeing that it goes through no less than twelve distinct preparations. These impurities consist in the natural oil of the cotton and particles of dust and dirt which are always flying about machinery when in motion, and should without doubt be entirely removed before the wick is to perform its duty in the lamp, and they must be removed in such a way as not to injure in any degree the cotton of which the wick is made. It will readily be seen that the wick really acts as a filter through which the oil must pass on its way to the flame, and unless a wick is free from impurities to begin with, it is utterly impossible for it to perform its duty properly. If in this boiling process chemicals of any description are used, either to improve the colour of the wick or to act more stringently upon it, just to that extent will the fibre of the cotton be injured and its burning power reduced. By continued experiments and practice, it has been found that a wick boiled in pure spring water gives the best result. The impurities of the wick will during this process pass into the water, and, to a certain extent, discolour it and float upon the surface. After this boiling bath, which varies in duration according to circumstances, the wick should be thoroughly rinsed in cold water, and then put into a hydro-extractor before being removed to hot closets heated to about 130° F. It is kept at this temperature until perfectly dry and without a particle of moisture remaining in it. The only process that now remains to be done is to make the wick up into its required state for the market, either in rolls or in cut lengths, and it is now ready for use.

"Perhaps it will be interesting to mention, in detail and briefly, each of the separate processes through which the cotton passes during its course of manufacture. We first of all have the cotton in its raw state as received in the bale from America. The machine it enters first is called an *opener*, for breaking up the cakes into which the cotton has been formed by the pressure of the hydraulic packing. When this is done, it passes to a machine called the *scutcher*, which removes the sand and seed, and then coils the cotton into the form of a *lap* ready for the next process, termed *carding*. This removes the lighter vegetable matters such as broken seeds,

dead leaves and motes, and also disentangles the knotted fibres, and delivers the clean cotton into a *can* ready for the *drawing-frame*, through which it next has to pass. By passing through this machine, the cotton gains much greater regularity and uniformity of weight. We next come to the *slubbing-frame*, which receives the *cans* of cotton from the drawing-frame; these are passed without doubling through this frame, being drawn out to four or five times their original length, and after being slightly twisted are wound on to bobbins. To give the cotton greater regularity and finish, it next passes through what is called the *intermediate frame*, which is a repetition of the process of the slubbing-frame. The bobbins from this intermediate frame are then passed on to the *roving-frame*, which draws off two bobbins together and forms a roving about two-thirds the thickness of the slubbing. It here receives a further small amount of twist and passes on to the *roving bobbin*. The roving bobbins are then placed in the creel of the mule and passed through the rollers without doubling, but with a draught of about eight to one, which means that the yarn is drawn out to the extent of about eight times its original length, producing a thread one-eighth of the thickness of the roving, and here it receives the amount of twist required for the purpose for which the yarn is intended, and on leaving the rollers is wound on to the spindle in the form of a *cop* which constitutes a perfect yarn in the single state. These cops are in their turn taken to the doubling frame to be doubled two, three, or more ends together as may be required. This doubled yarn is then taken to the warping-frame, and the requisite number of ends being put together for whatever width of wick may be required, is then made into the warp, the warp being taken to the loom, where it gets woven together with the binder, gut, and weft; these four uniting in this weaving process, and forming a perfect wick."

CHAPTER VI.

Independent Oil Supply, and modern arrangements for maintenance of constant Oil-level.

VARIOUS ingenious arrangements were introduced at an early date for preserving approximate uniformity in the level of the oil in the reservoir, by the use of a supplementary reservoir or otherwise, and thus preventing any increase in the demand on the capillary action of the wick. These arrangements, many of which have been described in Chapter I., were particularly useful when the comparatively viscous fixed oils were employed for illuminating purposes, but some of them have been adapted to the modern petroleum lamp.

Thus, the "bird-fountain" principle s employed in what is known as the reading-lamp, for use with petroleum, while the "Carcel" or "Moderator" system has been adopted in the lamps of Peigniet-Changeur, Fig. 225, and of Aria, Figs. 226 to 228; also in a lamp recently introduced by Hinks.

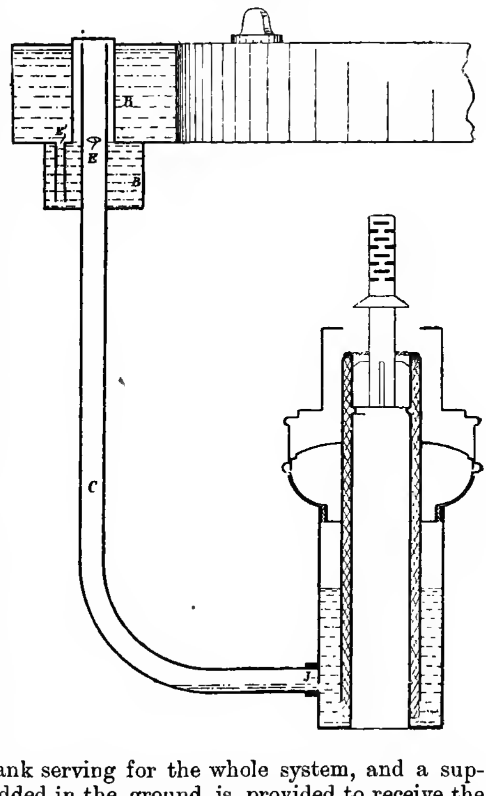
In the "well and bucket" lamp of Hinks, the oil container from which the wick draws its supply, can be caused to descend into a well or reservoir forming the base of the lamp, and can thus be refilled.

In the "Pneumatic" lamp of Defries and Feeny, Fig. 247 (Patent No. 7782, A.D. 1887, and No. 6868, A.D. 1888), the oil is supplied to the wick-tube from a raised reservoir by a tube *C*, which opens into an air chamber *B* in the reservoir and communicates with the wick-tube through perforations in the lower part of a plate *J*. The oil passes into the chamber *B* through the channel *E'*, and gains access to the tube *C* through the orifice *E*. The tube *C* forms part of the air chamber, and the oil flows to the wick-

tube until the level therein is as high above the perforations in the plate J, as the oil in the reservoir is above the opening E. This arrangement thus permits the descent of the oil as fast as it is consumed. Various modifications, such as the bending of the upper end of the tube C' into a siphon, may be used in lieu of the chamber B.

Fig. 248 shows a lamp patented by T. and E. Penn (No. 10,892, A.D. 1889) which is intended for burning heavy oils. The wick-tube a has a perforation or perforations covered with fustian or other absorbent material d, enclosed by an outer casing C, to which pass tubes D D'. The part of the wick within the reservoir is entirely enclosed by a tube a^3 closed below, so that the wick is fed by the fustian, which again is supplied through the tubes D D'. The flow of oil in these tubes is started when the lamp is lighted, by a few strokes of a small pump v, or by the use of some alternative arrangement, such as a collapsible vessel extended by a spring. The oil continues to flow automatically as fast as it is consumed.

FIG. 247.



Several inventors have introduced arrangements by which the various lamps throughout a dwelling or in an outdoor or other lighting system, may be continuously supplied with oil from a single reservoir. Thus, the arrangement previously described in connection with the burner illustrated in Fig. 207 (p. 273), was introduced in 1867 by Brash and Young, and the "Ross" system, Fig. 244, in 1885 by Ross and Nolan. Defries has also patented a method of arriving at the same result.

In Silber's system, described in the Journal of the Society of Arts for December 23, 1870, and represented in Figs. 249 and 250, each floor X Y of a house is fitted with a reservoir H, which supplies all the lamps on its level. Each reservoir has a chamber F at the back, which is replenished from an overhead tank serving for the whole system, and a supplementary reservoir D, imbedded in the ground, is provided to receive the oil in case of fire. Each reservoir has an overflow pipe, and is fitted with a float which opens a cock when the oil-level falls, and causes the entrance of a further supply.

The system patented by T. and A. E. Penn (No. 8882, A.D. 1888, and No. 8389, A.D. 1889), comprises the supply of the oil to the various lamps of a system through pipes, similarly to gas, with various arrangements of automatically controlled valves. Fig. 251 shows one method of applying this invention to a double pendant lamp. The oil flows through a tube I traversing the stem of the pendant, and through an inclined passage Q and a horizontal passage H, into a chamber, whence it is distributed to the two

FIG. 248.

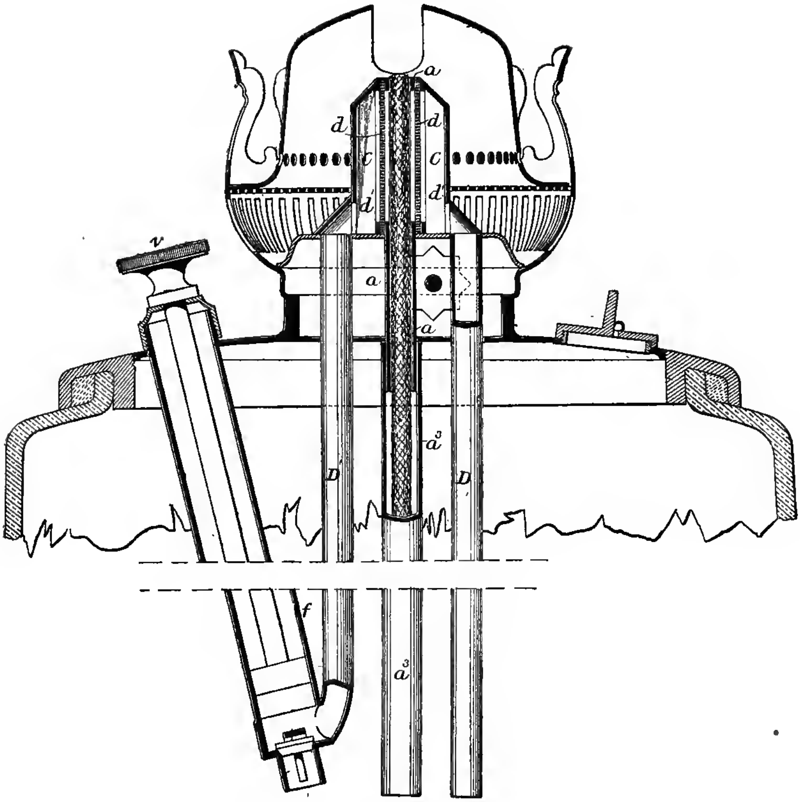


FIG. 249.

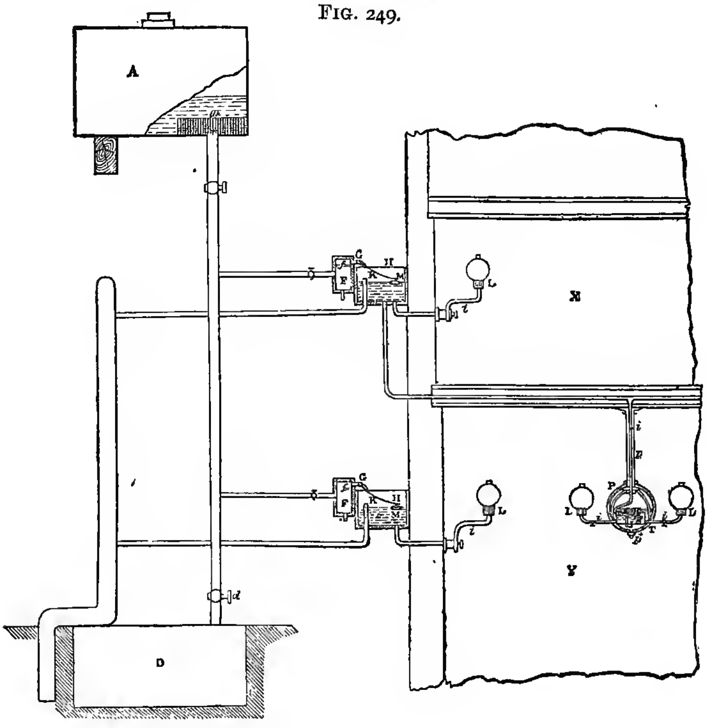


FIG. 250.

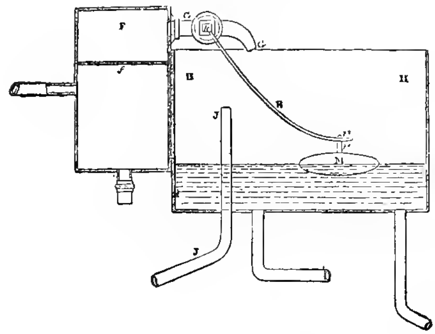
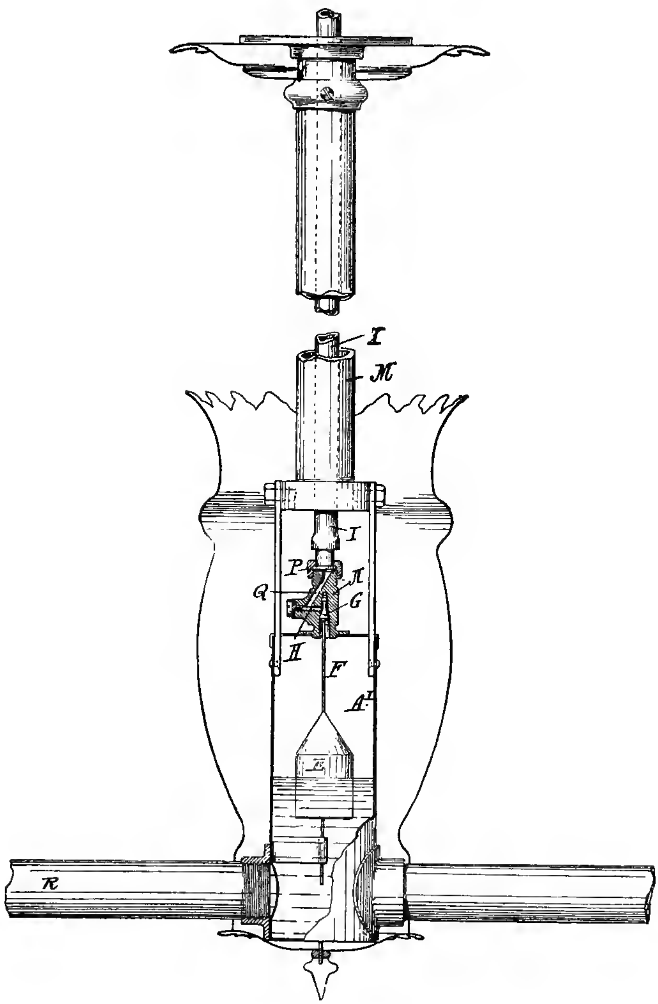


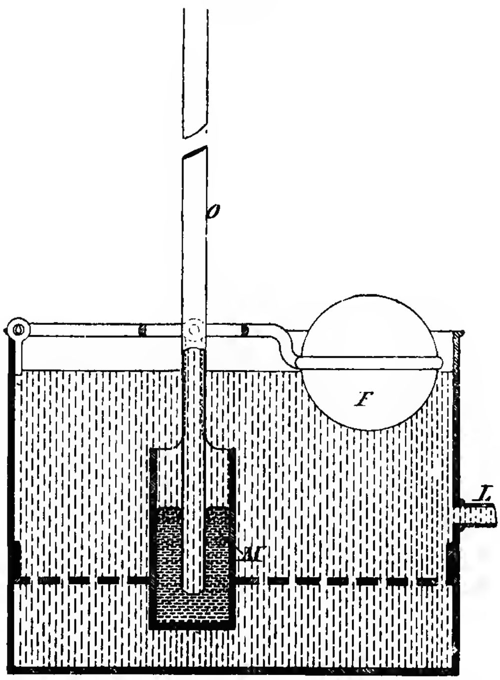
FIG. 251.



lamps by tubes *R*. The flow of the oil is controlled by a valve *G*, which is opened as soon as the consumption causes the descent of a float *E*. In the case of single burners, the regulating arrangements are fitted in the reservoir of the lamp itself, the float being preferably annular in the case of central-draught burners.

In a modification, an inner vessel constituting the float, is so constructed as to serve as a reservoir for the oil, into which the wick dips, a valve opening for the admission of oil to an outer vessel as the buoyancy of the inner floating chamber is increased by the consumption of its contents. The oil which thus gains access, overflows into the inner vessel until the increased weight closes the valve.

FIG. 252.



The Fenby system (Patents No. 3067, A.D. 1887, No. 7616, A.D. 1888, and No. 12,345, A.D. 1888) for regulating the supply of oil from a raised tank to a lamp reservoir, depends for its action on the balancing of the pressure of the oil in the supply tube *O*, Fig. 252, by a short column of a heavier liquid, such as mercury. In the arrangement shown, the tube *O* dips into mercury contained in a vessel *M*, suspended from a lever which carries a float *F*, resting upon the oil in the reservoir, the exit *L* leading to the lamp or lamps. When the oil flows too freely, the float lifts the vessel *M*, so that the increased immersion of the tube in the mercury checks the supply, whilst, on the other hand, if the consumption exceeds the supply, the descent of the vessel *M* permits of a greater flow. The inventor describes several alternative automatic and other arrangements for regulating the flow. The requisite head of oil for supplying a whole system of lamps on different levels may be obtained by the aid of a head of water.

CHAPTER VII.

Extinguishing Appliances.—Automatic Extinguishers.—Elevating Gallery for Lighting.

It is now usual to fit the larger burners with some description of extinguishing apparatus. The earliest form of extinguisher appears to have been that which was employed in the improved "Brighton" burner, patented in 1862. This burner has an air-deflector or button, the stem of which rests upon a pin passing horizontally through the burner. On withdrawing the pin the button drops on the wick and extinguishes the flame. In the "Waterbury" burner, the dropping of the button is also effected by the drawing out of a pin, but on the pin being released the action compresses a spring and the button resumes its normal position. The button-extinguisher of the "Star" lamp is brought into action by depressing a thumb-plate, and in this case also the button returns to its original position when the pressure is removed.

FIG. 253.

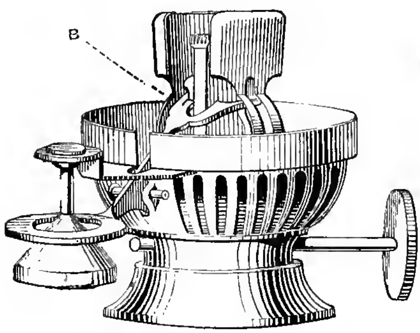
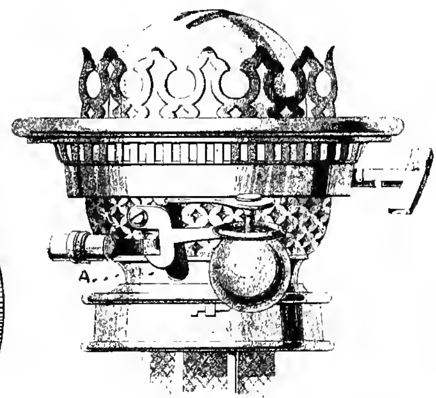


FIG. 254.



Automatic Extinguishers.—A large number of automatic extinguishers, some of which may also be operated by hand, have been introduced. Fig. 253 shows one of the arrangements fitted to the "Duplex" burners of Joseph Hinks and Son. It consists of two plates having slots, in which the forked end B of a lever works. At the opposite end, the lever terminates in a ring, within which a weight is suspended. While the lamp is burning, the plates or shutters are held apart by a catch, but upon the lamp being tilted the upper part of the suspended weight is brought into contact with the ringed end of the lever in such manner that the catch is released and the plates close upon the wicks by the action of springs. The lamp is similarly extinguished when the weight is lifted by hand. In a modification of this, Fig. 254, the spring which closes the extinguisher-plates is released through the medium of the pivoted hooked lever A. In one of the "Duplex" lamps of Wright and Butler, the extinguisher is automatically brought into action as soon as a weighted rod suspended beneath the burner passes to any material extent out of a line perpendicular to the base of the lamp.

Dowdall's automatic extinguisher (Patent No. 14,957, A.D. 1890) consists of a top-heavy hollow cap, having an opening at the top, corresponding with the size and shape of the wick-tube, which it encircles. The extinguisher,

which stands on a rocking platform surrounding the wick-tube, tilts over and extinguishes the flame when the lamp is much inclined in either direction.

Fig. 255 represents one of the automatic extinguishers patented by Ogden and Anderson (No. 657, A.D. 1883). To light the lamp, the sliding extinguishers *c* are lowered by means of a lever *g*, acted on by a spring, and held at the end by a trigger *h*, pivoted to the burner frame. Immediately beneath the trigger is a spindle *d*, terminating in a disc, which rests on another disc attached to a spindle e^1, weighted at e^2, and having a ball and socket-joint at e^3. The upsetting or inclination of the lamp causes the weight e^2 to lift the spindle *d*, so that the trigger is released and the extinguisher closed.

In the arrangement of King and Godfrey, Fig. 256 (Patent No. 1427, A.D. 1885), the plates *d d′*, which close over the wick to extinguish the flame, have arms *e e′*, between which is fitted a cam-plate *f*, carried by a rod *g*, having a weighted arm *i*. When the lamp is tilted, the weight turns the rod *g*, so that the cam-plate separates the arms *e e′*, and thus closes the ex-

FIG. 255.

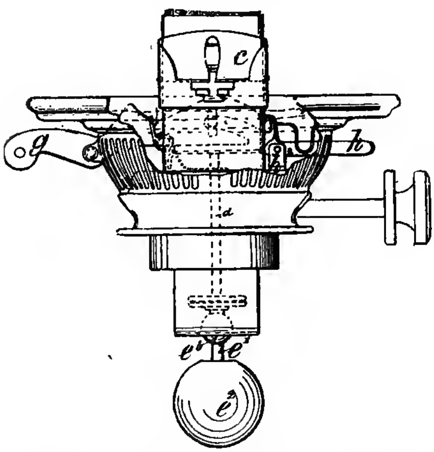
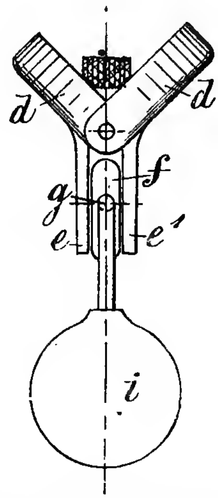


FIG. 256.



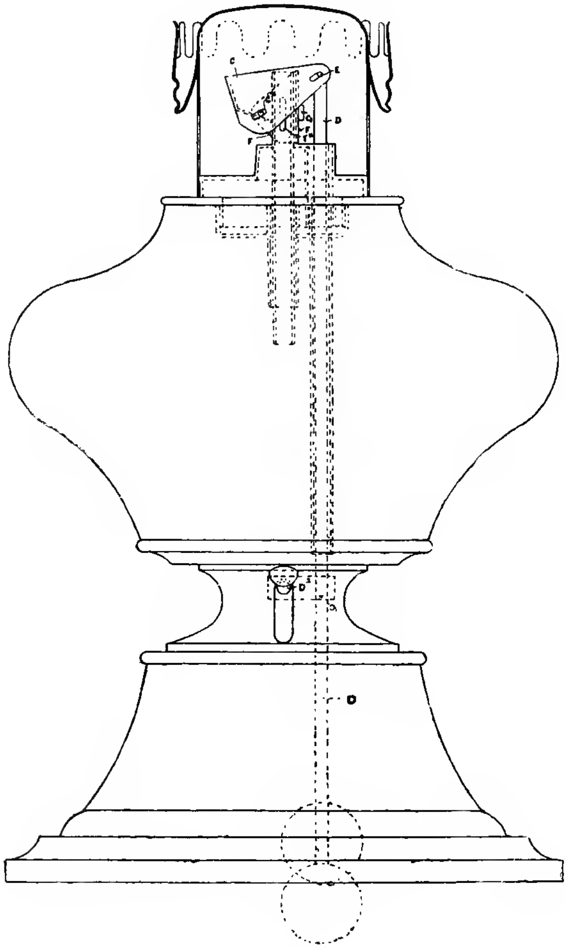
tinguisher. The lamp may be similarly extinguished by moving the weight. The base of the lamp is preferably shaped elliptically, so that the lamp, if upset, shall take up such a position that the rod *g* is horizontal and the arrangement will act properly.

Fig. 257 exhibits the extinguishing appliance fitted to the "Shaftesbury safety" lamp (Phillips' Patent No. 11,426, A.D. 1886). The extinguisher-cap C is pivoted on the flat-wick tube, and is connected with the weighted rod D by the pin E, which passes through a slotted hole. When the lamp stands on a table or other support the weight rests thereon, and when it is carried the rod D is supported by grasping the sliding collar attached to it by the cross-bar D^2. When, however, the lamp is tilted or overturned, the rod D falls and draws the cap C over the wick, as in Fig. 258, while at the same time a plate F, sliding on a stud G, and continued round the wick-tube, is raised, so that the wick is entirely enclosed and the flame extinguished. In the case of Argand burners, Phillips adopts the arrangement shown in Fig. 259. The button or air-diffuser G is attached to the weighted rod D, and forms the extinguisher, in conjunction with a tube M, which surrounds the outer wick-tube, and is raised on the descent of the rod. The raising of

the tube M is effected by the pressure of as pin S, exerted through rocking-levers and pins, upon the pendant rods N.

In Johnson's extinguisher (Patent No. 7203, A.D. 1888), the burner, Fig. 260, is fitted with two bell-mouthed or flaring cups i, each containing a loose ball j, and having lids g^2 which form the lower arms of extinguishing shutters g on each side of the wick. When the lamp is tilted or overturned,

FIG. 257.



the tendency of the balls to pass out of the cups causes the lifting of the lids, and the extinguishers are thus closed over the wick.

The "Victoria safety" lamp of Sherring, previously described, Fig. 237 (p. 290), has an extinguisher consisting of two caps C D which close automatically when the lamp is overturned.

Fig. 261 shows Postlethwaite's automatic extinguisher, which is fitted with two spring shutters closing over the wick. The burner dome, which constitutes an essential part of this extinguisher, is made in two parts, the horizontal division being just below the slot. The upper part is of

FIG. 258.

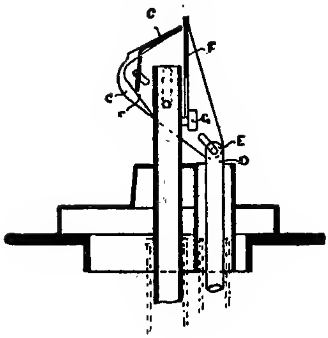


FIG. 259.

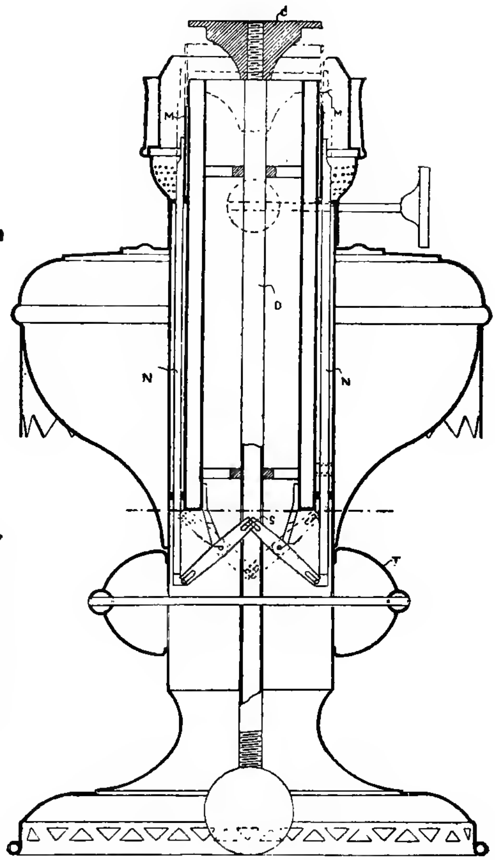


FIG. 260.

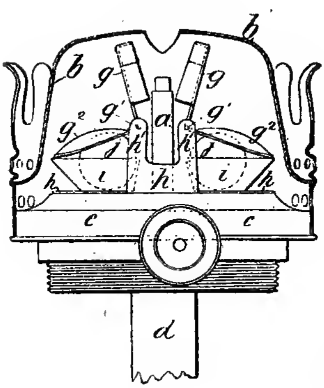
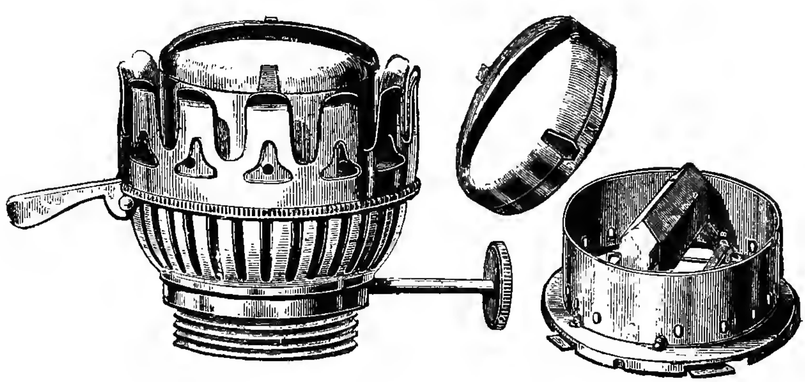


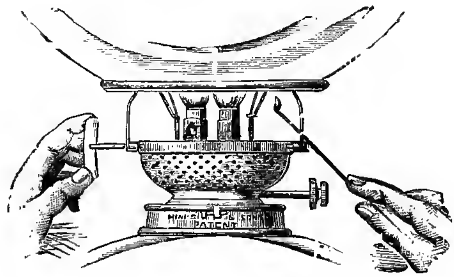
FIG 261.



metal of considerable thickness, and is sufficiently weighty to hold the spring-shutters open. When this portion of the dome is displaced by the overturning of the lamp, the shutters are raised by the springs and extin-

FIG. 262.

FIG. 263.



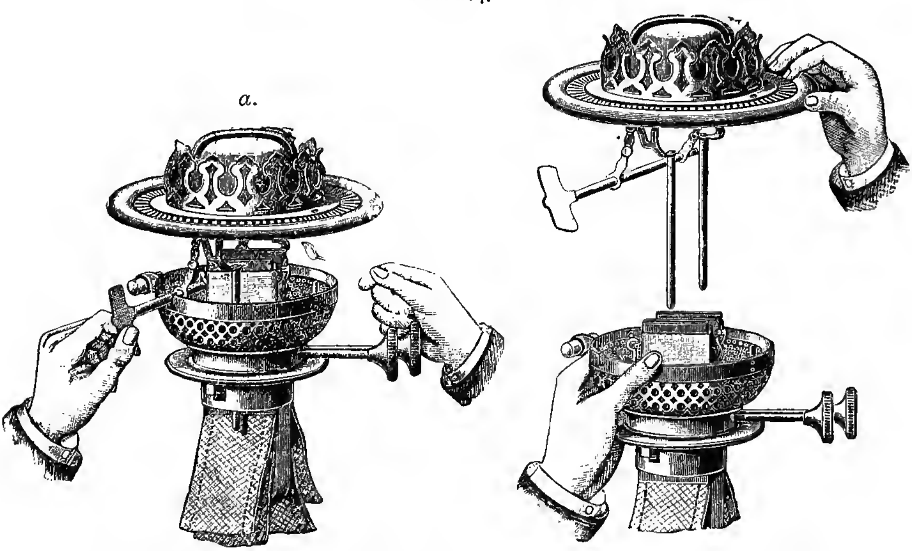
guish the flame. They may also be raised at will by the use of a lever, with which the burner is provided.

In the "Water safety" lamp of Devoll (Patent No. 4919, A.D. 1887), Fig. 262, the reservoir is surrounded by a water-jacket. If the lamp is

FIG. 264.

b.

a.



overturned, the water runs into a cap surrounding the air-holes of the burner and extinguishes the flame.

Gallery Elevators.—Several inventors have introduced arrangements for raising the gallery carrying the chimney and globe to facilitate lighting

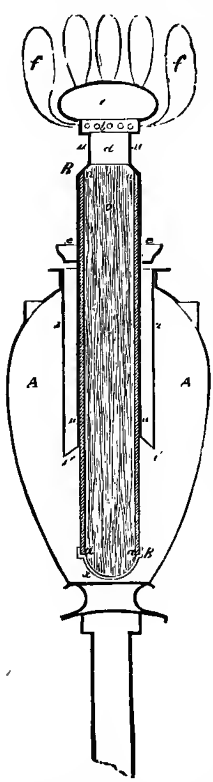
and trimming. In Hinks' "Duplex" burner, Fig. 263, the gallery is raised vertically by turning a key, whilst in Rettich's "Mitrailleuse" burner the gallery slides up, without the use of a key, sufficiently to permit of the insertion of a taper. In Wright and Butler's arrangement, Fig. 264, *a* and *b*, the raising mechanism admits of the ready removal of the gallery (as shown in *b*) to facilitate the cleaning of the burner.

CHAPTER VIII.

Mineral Spirit and Vapour Lamps.

PETROLEUM spirit or benzoline is largely employed as an illuminant for domestic purposes in what are termed "sponge-lamps." These are small chimneyless lamps, the metallic reservoir of which is filled with sponge or other absorbent material, the spirit being burned with a solid cylindrical wick. The reservoir is intended to contain only as much of the illuminant as is taken up by the absorbent material, and there is thus no risk of the highly inflammable spirit being spilled in the event of the lamp being dropped or overturned, the only danger connected with the use of these lamps being that which attends the charging of the reservoir.

FIG. 265.



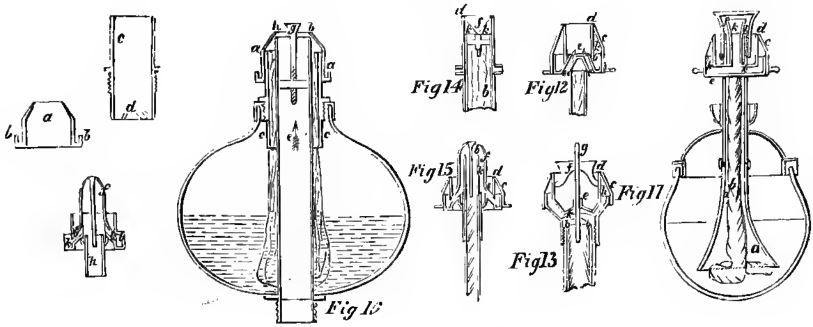
In the majority of the lamps which have been introduced from time to time for use with the more volatile descriptions of hydrocarbons, the illuminant is converted into vapour and is burned at a jet with or without previous admixture with air. Lamps constructed on this principle were at one time employed on the Continent for burning a mixture of liquid hydrocarbons and alcohol, and were known as vapour lamps or self-generating gas lamps.

The simplest form of petroleum-vapour lamp consists of a reservoir having an opening at the top, communicating with the air, and provided at the base with a tube extending downwards and terminating in an Argand burner. The reservoir being charged with some absorbent material saturated with a very volatile description of mineral spirit, such as gasoline, the heavy vapour of the liquid flows through the tube by gravitation under sufficient pressure to furnish a steady flame of high luminosity, similar to that produced by coal gas.

In the vapour lamp of Lüdersdorff, of Berlin, oil of turpentine mixed with four times its volume of 90 per cent. alcohol was used. This mixture, though yielding a feebler light than is obtained from turpentine alone, was found to be more manageable and less liable to smoke, on account of the lower proportion of carbon which it contained. The construction of the lamp is exhibited in Fig. 265. The burner-tube *B*, enclosing the wick, extends almost to the bottom of the reservoir *A*; it is contracted at the top and surmounted by a metal knob *c*, at the base of which is a series of perforations. Before using the lamp, a little alcohol is burned in a cup *e* surrounding the burner-tube, so as to volatilise the illuminant raised by

the wick. The vapour ignites as it issues at the perforations, and the flame produced heats the knob c. When the lamp has thus been lighted, the heat conveyed from the knob effects the continuous conversion of the illuminant into vapour. The upper part of the burner-tube is surrounded

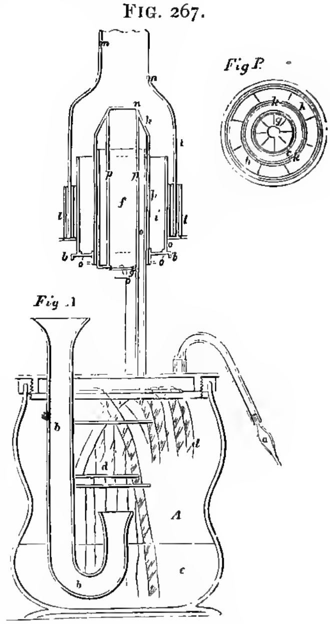
FIG. 266.



by an annular air-space, formed by an outer tube, to prevent conduction of heat to the spirit in the reservoir.

The French Gasogène lamps, introduced for burning a mixture of alcohol and coal-tar naphtha, were constructed on the same principle.

FIG. 267.



The use of a mixture of one part of coal-tar naphtha with two parts of wood spirit, or four of acetone, was at an early date proposed by Mansfield, who introduced the lamps shown in Fig. 266 for burning it. The wick employed for raising the illuminant may be tubular, as in *Fig. 16*, or solid, as in *Fig. 11*. *Figs. 12* to *15* show various burners suitable for use with solid wicks. The size of the burner-slit or orifice d is adjusted by a movable cone or cylinder c, and the part f which becomes heated and causes the vapour to be evolved from the wick may be a hollow button or cap, as in *Fig. 11*, or a solid button through which a rod g passes to the wick, as in *Fig. 13*; or it may be a solid button attached to a pin passing, as in *Fig. 14*, through a crosspiece to the wick, or a cap which, as in Fig. *15*, is movable upon the wick-holder. In the arrangement shown in *Fig. 16*, the heat is conveyed to the wick by a button g, and the exterior cone a slides on the wick-holder c, which is provided with hooks d for supporting the wick.

Mansfield proposed to employ benzene (benzol) as an illuminant in the lamp illustrated in Fig. 267. The benzene reservoir A contains a number of cotton wicks suspended in a wire frame over the lower end of the wide curved tube b, through which air is drawn by the action of the chimney during the burning of the lamp. The burner is of the Argand form. The lamp is lighted by blowing air through the

mouthpiece *a*, until a flame is produced, and the chimney has become heated; air subsequently flowing in a continuous current through the tube *b*, and becoming charged with the vapour of the benzene in its passage through the reservoir. Fig. 268 represents a modified form of this lamp, also introduced by Mansfield, for use with hydrocarbons less volatile than benzene; *a* is a tube through which air passes upwards to the chamber *b*, which is so placed as to be heated by the burner. *c* is an inner tube through which the heated air travels downwards into the reservoir or evaporating vessel *e*, and *f* is a branched tube through which the mixture of air and vapour ascends to the burner.

Lamps in which coal-tar naphtha is burned without a wick, in conjunction with an air-blast, have been introduced by Beale (Patents No. 6537, A.D. 1834, and No. 7501, A.D. 1837) and by d'Hanens. In the Beale lamp, the air passed through and became charged with the naphtha, producing a single

Fig. 268.

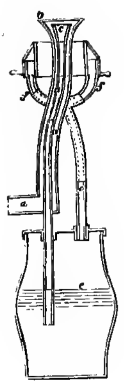
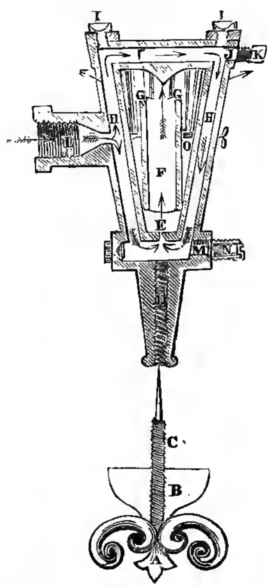


Fig. 269.

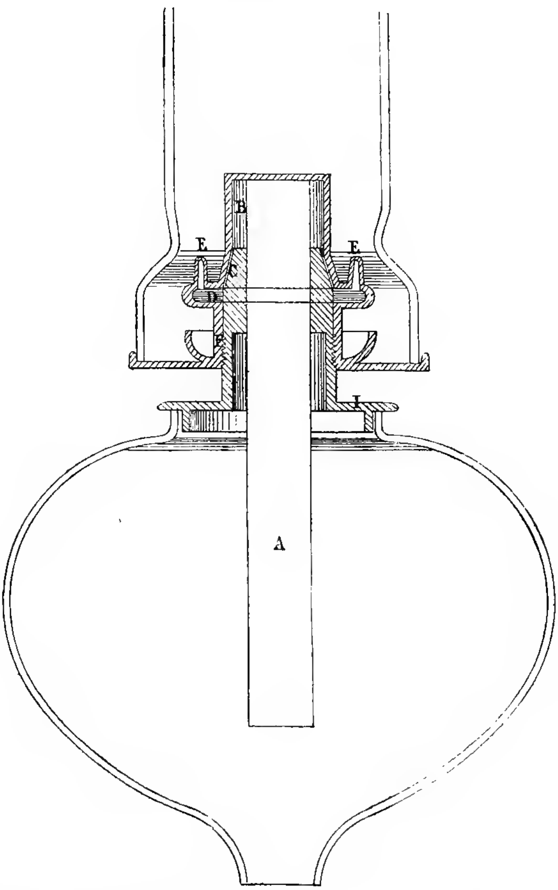


long flame when the burner was supplied with a double air-current; while the lamp of d'Hanens, which had a knob surrounded by perforations, similar to that with which Lüdersdorff's lamp was fitted, gave a ring of single flames.

The conical tin lamp so largely used by costermongers and others for obtaining an outdoor light, is one form of a lamp introduced by Read Holliday (Patents No. 12,015, A.D. 1848, and 12,965, A.D. 1850) for burning coal-tar naphtha. The inventor describes a large number of modifications for indoor and outdoor use. In all of these the burner, which consists of a perforated flat or annular chamber, requires to be heated before the naphtha is allowed to flow to it from the reservoir, but when the flame has been kindled, the heat emitted vaporises the liquid before it escapes from the burner. The flow of the spirit is regulated by means of a tap, or by the introduction of cotton-wool or other fibrous material into the supply tube. In the case of the lamps fitted with reservoirs below the burners, the oil may be raised to the burner chamber by a wick or otherwise. In one form of lamp having several burners, one of the burners serves as the

vaporising chamber from which the others are supplied. In most of the burners, the vapour is mixed with air before combustion. Fig. 269 exhibits the construction of the burner of a lamp employed for outdoor lighting. The oil flows from the overhead reservoir through a regulating stopcock, into passages H in the burner; here it becomes vaporised, the vapour passing through a fine aperture E and a tube F, and being deflected by a cone placed above wires G. The stream is thus subdivided and several jets of flame are produced. Apertures I J M, closed by screw-plugs, facilitate cleaning

FIG. 270.



and a screw B C regulates the passage of the vapour through the opening E.

Fig. 270 depicts one of three arrangements patented by Gedge (Patent No. 13,018, A.D. 1850). The spirit is raised to a chamber B by a fireclay wick A, and is there vaporised by the heat of the flame at the circular burner E. A circular stopcock C adjusted by a screw F, regulates the passage of the vapour to the burner.

King (Patent No. 1863, A.D. 1856) has described a spirit lamp provided with improved arrangements for supplying air to the flame, and preventing the conduction of heat to the spirit in the reservoir.

A lamp for which Broad obtained provisional protection in 1857 (No. 2489), is described as being furnished with an Argand burner, through which passes a tube provided with a separate wick. The Argand tube has a metal guard at the top, whilst the inner tube, which extends somewhat above the Argand tube, terminates in a perforated button. On lighting the wick of the Argand burner, the button forming the top of the inner

Fig. 271.

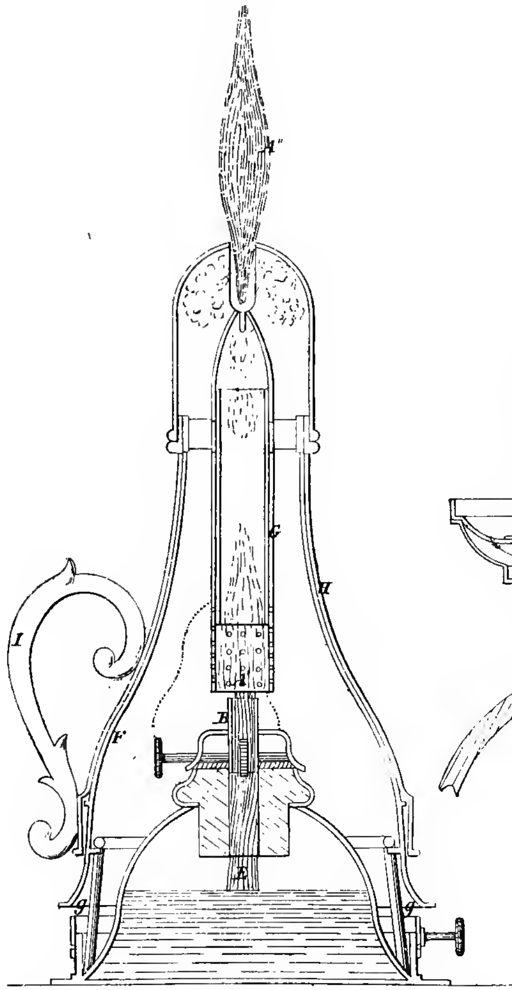
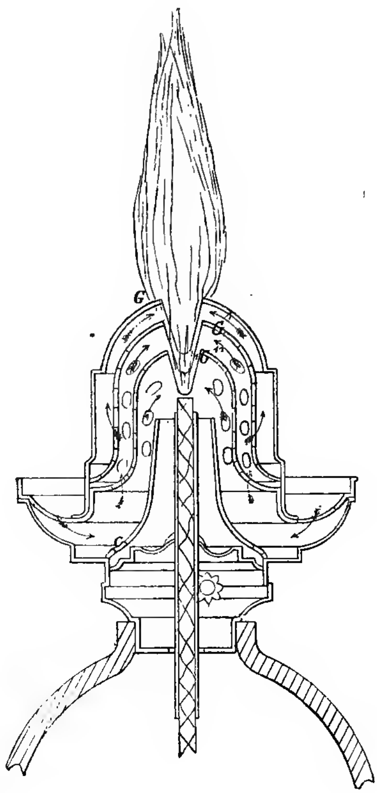


Fig. 272.



tube becomes so heated as to vaporise the oil, which burns at the perforations as a separate flame, or coalesces with the outer flame.

Fig. 271 represents a lamp patented by Newton (No. 1488, A.D. 1858), in which the necessary heat for volatilising the illuminant is furnished by a flame burning at the end of the wick in a tube *G*, perforated below for the entrance of air. The products of the incomplete combustion which occurs in this flame, together with the vapour from the heated wick, and the air drawn in by the flame, pass up the tube and give a luminous flame at

A''. The lamp is provided with a fixed case F, surrounded by a case H, preferably non-conducting, having a handle I. The casings F H are furnished with apertures which may be made to coincide so that access to the wick may be obtained. Air is admitted to the flames through a space g.

In a chimneyless lamp, Fig. 272, patented by Newton on behalf of Racey (Patent No. 1162, A.D. 1859), and in some respects resembling the "Anucapnic" burner patented by Rowatt (see p. 269), air is supplied to the flame through three perforated cones, G, G', G'', arranged in the manner shown in the illustration.

Lamps in which the oil is raised by a wick, and burned after volatilisation and admixture with air, have also been patented by Newton on behalf of residents abroad (Patent No. 2398, A.D. 1860, and 2958, A.D. 1866). One of

FIG. 273

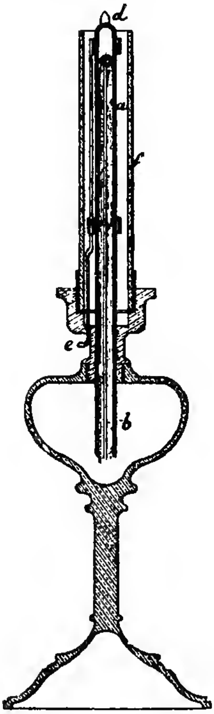
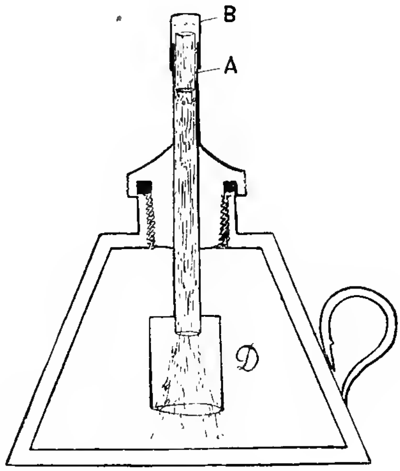


FIG. 274.



the lamps described in the specification of the patent 2398 of 1860 is fitted with a clockwork-driven fan for supplying air to the burner.

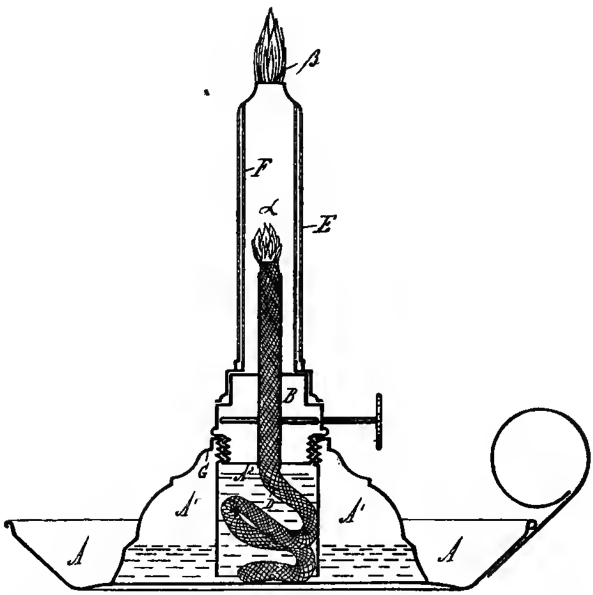
Fig. 273 shows a lamp introduced for burning the vapour of benzoline or other hydrocarbons, by Pouschkareff (Patent No. 5832, A.D. 1883). The illuminant is raised in a tube a by a wick, to such a height that the heat of the flame, which burns at openings in the end of the tube, volatilises it as rapidly as it is consumed. To effect the requisite heating, a ring of silver or other metal furnished with projections d is fitted upon the tube. The ring is carried by a rod terminating in a hook e, and may be adjusted to vary the amount of volatilisation according to the light required. A silver wire bent so as to encircle the flame may replace this arrangement, or as another alternative the end of the tube a may be surmounted by a cap, so perforated or slit as to give a flame of the desired form.

The "Gas-maker" lamp, Fig. 274, patented by Wood (No. 2537, A.D.

1884), has two wicks, a long, tightly compressed feeder and a short, loose, asbestos, cotton, or other wick A above it. A perforated cap B forms the burner, and communicates the heat downwards to volatilise the liquid. An air-chamber D may be added to prevent flooding of the wick in case of the lamp being overturned.

Fig. 275 shows a vapour lamp introduced for burning Russian petroleum, by Chandor (Patent No. 10,234, A.D. 1885). As in the lamp shown in Fig. 271, the products of the imperfect combustion of a flame a at the end of the wick, become mixed with air and burn with a luminous flame at β. The air is admitted through a cylinder of wire gauze or perforated metal F, surrounded by a tube E, which may be perforated throughout its whole length or at the top or bottom only. Air may also be admitted through perforations in the casing B. The reservoir consists of inner and outer chambers A^2 A^1, the latter of which is open to the air at G. The action of the flame

FIG. 275.



a is stated to raise the level of the oil in the chamber A^2, and thus supplement the capillary attraction exerted by the wick. In a modification (Patent No. 12,336, A.D. 1887), shown in Fig. 276, a chimney is used and the burner is enclosed in a ground-glass or porcelain cylinder c, which imparts heat to the air entering at perforations e. The wick-tube is surrounded by a tube g, to which air is supplied through openings h.

Another lamp in which the vapour is generated by the use of a secondary flame, is that of Stringfellow (Patent No. 7578, A.D. 1886). In this lamp, Fig. 277, the flame burns beneath a cap e, and the requisite amount of air to give a flame at e' of the maximum luminosity is admitted through slots f which may be more or less closed by means of the regulator g. The cap may consist of an inner and outer shell, between which air also passes to the base of the flame. Stringfellow's patent also includes an Argand burner with a baffle plate or "button" for directing a current of air on to the flame, as well as suitable tubes and perforations for supplying the air which is

mixed with the vapour. Sometimes the vapour generated by a single secondary flame is conveyed to two or more burners.

Fig. 278 exhibits the construction of the "Sun Automatic Gas-lamp," patented by Hearson. The mineral spirit flows from a reservoir into a tube F containing a wick, and is there vaporised, the vapour passing through a conical orifice, into the burner tube H, together with the requisite quantity of air. The supply of vapour to the burner tube is regulated by a

FIG. 276.

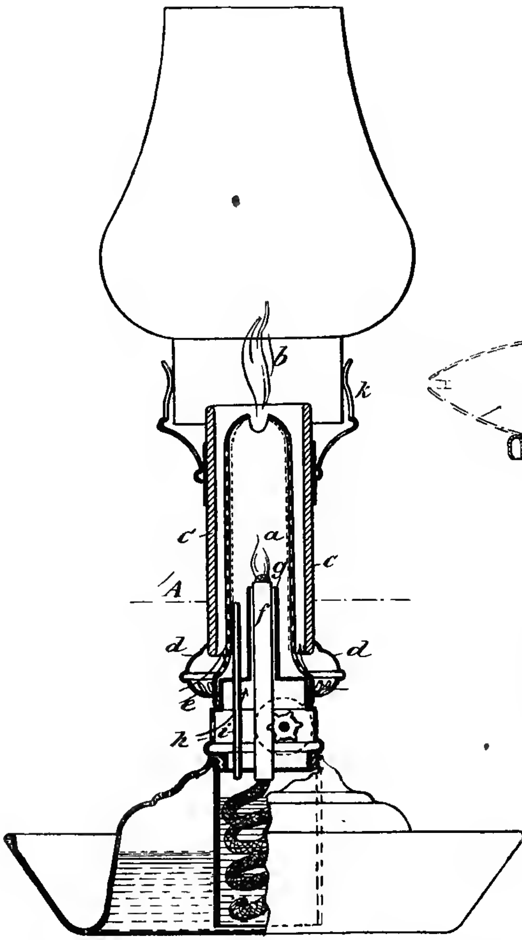
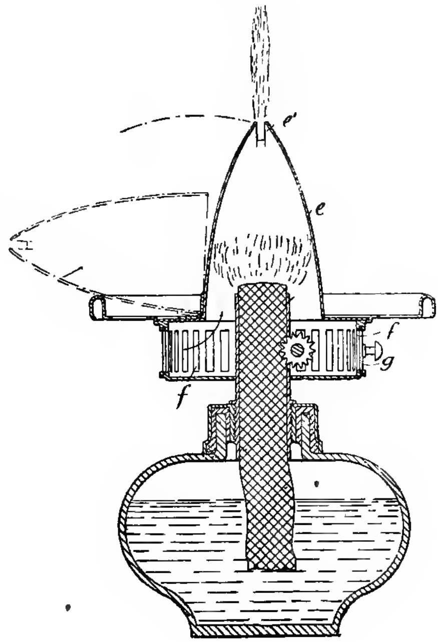


FIG. 277.



screw J. Two small holes in the tube H produce fine jets of flame which impinge on the inner faces of curved plates *g*, and thus assist the vaporisation of the spirit in the tube F. At starting, the reservoir valve is opened fully, so that some of the spirit runs into a cup K. The valve is then closed, the spirit ignited, and, when sufficient heat has been imparted to the burner for the automatic generation of the vapour, the valve is partially reopened.

In the "Orion" lamp, introduced by Messrs. Whittle and Son, and intended principally for lighting streets, mines, &c., the oil from an over-

Fig. 278.

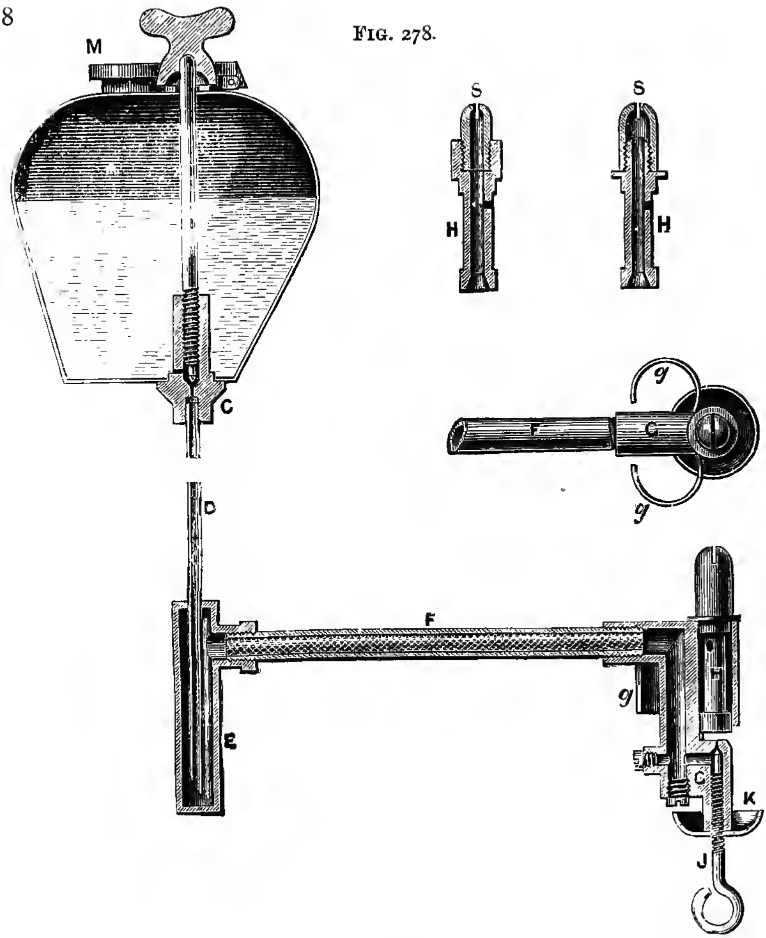
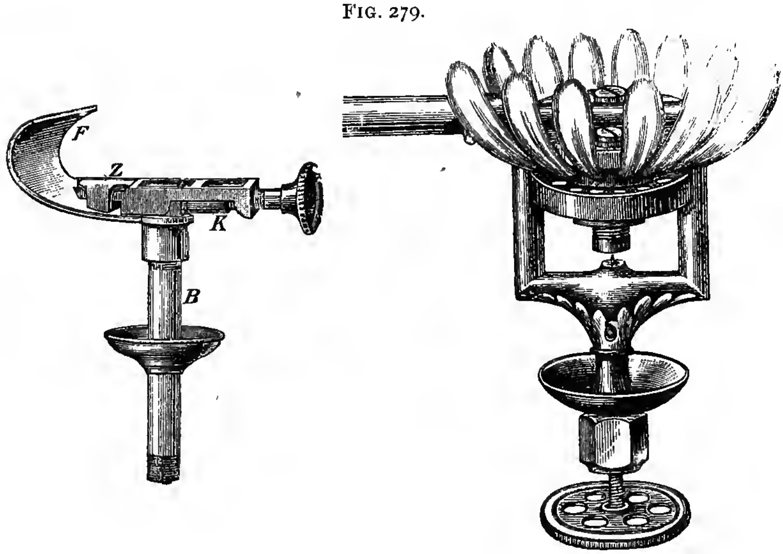


Fig. 279.



head reservoir passes through a tube plugged with cotton, and fitted with a regulating tap. It issues from a fine aperture, and, impinging on a previously heated brass plate, is volatilised. The flame burns at a slit resembling that of an ordinary batswing gas-burner.

Fig. 279 represents a flat-flame burner and a circular burner, introduced by A. and O. Huff (German Patent, No. 36,279). In each, the oil is supplied from a reservoir by a wick, and is burnt in the form of vapour. In the former, the flame burns at a slit *Z*, on an adjustable slide *K*, and heats a plate *F*, with the result that the oil is volatilised at the end of the wick. In another form of the flat-flame burner, the tube *B* is elongated and furnished with a slit. In the case of the circular burner, the supply tube passes over the burner, so that the plate *F* is unnecessary. A small quantity of spirit is burned in a cup beneath the burner to start the lamp.

CHAPTER IX.

Blast or Spray Lamps.

In these lamps, which are of comparatively recent introduction, and are principally employed to light large spaces where the flame may be exposed to wind or rain, the oil is burned in the form of spray or vapour in a blast of air or of steam and air. The lamps of Beale and d'Hanens, mentioned in the last chapter, may be considered as belonging to this class, although the air was supplied at a considerably lower pressure than in the modern lamps, the pressure in Beale's lamp only amounting to from half an inch to three inches of mercury.

In the "Lucigen" spray lamp of Lyle and Hannay (Patents No. 7162, A.D. 1885; 1626, A.D. 1886; 1632, A.D. 1887; and 3113, A.D. 1887; *vide* also Hannay, "Jour. Soc. Arts," 1887, vol. xxxvi. 57), the blast is so powerful as to break up the oil into extremely fine particles, and to produce a very stiff flame, whilst the air supply is so adjusted as to give a bright light without evolution of smoke or unconsumed vapour.

Fig. 280 shows the common form of this lamp. The air is supplied at B, at a pressure of about 20 lbs. to the inch, and passes through a tube into the tank, from which it forces the oil up a tube F, furnished with a cock G, to the burner. The necessary quantity of air for breaking up the oil into spray, and ensuring perfect combustion, passes through a controlling cock and a tube I, into a coil superheater K, Figs. 280 and 281, in which it circulates round the flame, and becomes highly heated. Thence it passes down a tube L into the burner, heating the oil, and mixing with the oil-spray and vapour as these are driven out through the nozzle *13*.

Owing to the form of the burner, air is strongly drawn in round the base of the flame through perforations in the outer shell of the burner, and is heated before reaching the point where combustion occurs. A small permanent flame, supplied by an asbestos or other wick *17*, relights the spray in case of accidental extinction.

With the ordinary large-size Lucigen, a tapering solid flame, about 3 feet in length and 9 inches in diameter, of an illuminating power equal to 2000 to 2500 candles, is produced. The lamp is usually worked with heavy hydrocarbon oils or creosote, of which it burns about two gallons per hour. Smaller apparatus, giving the light of from 400 to 800 candles, and a powerful Lucigen with a triplex burner of 9000 to 11,000 candle-power, are also constructed.

When the size of the flame does not require frequently adjusting, the earlier form of the Lucigen, Fig. 282, may be used. In this lamp, the air passes through an india-rubber tube O into a vertical superheater E, which

FIG. 281.

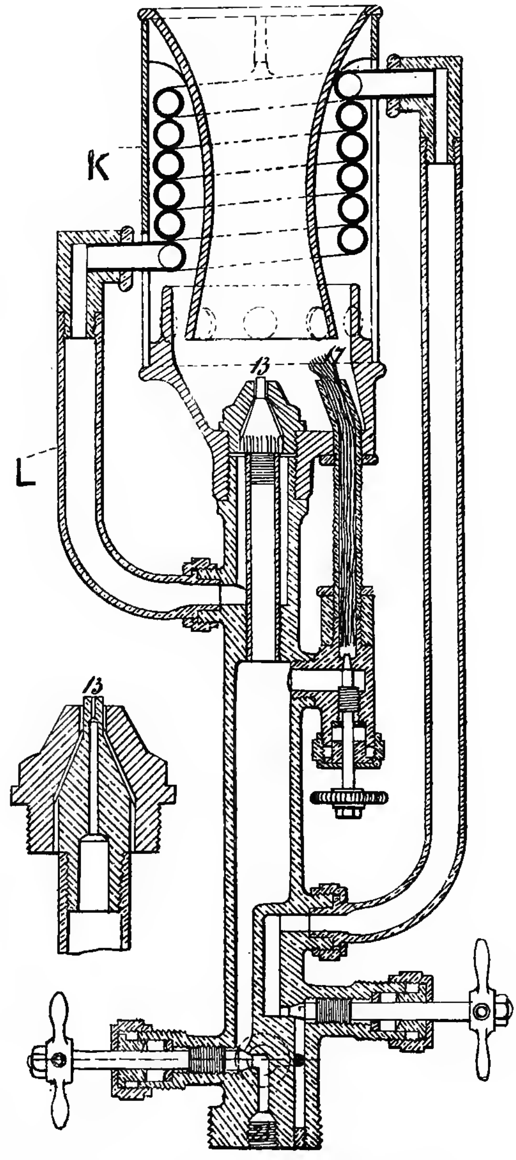
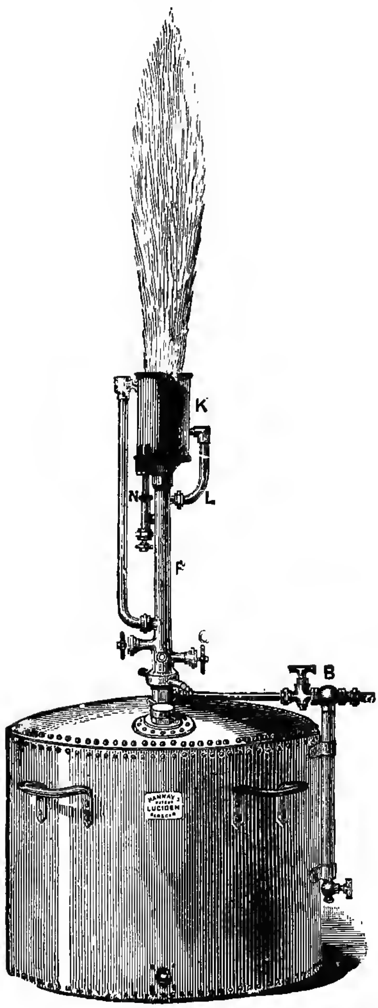


FIG. 280.

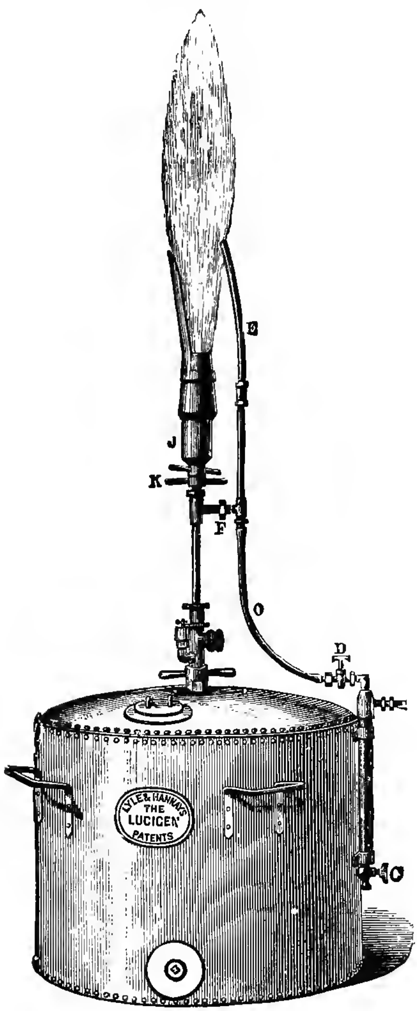


consists of an internal and an external tube. The air travels up the inner tube and down the outer tube, which is of copper, and having thus become heated, passes to the burner at F. The tube H supporting the burner is also double, so that the compressed air passes down within the outer tube and forces the oil up the inner tube to the burner. The air and oil

supplies are simultaneously regulated by screwing the burner J up or down, and locking it by a jam-nut K.

Where an air-blast is not obtainable, steam may be used, the diminution of the light caused by the presence of the water vapour being but slight, on account of the combustion being mainly supported by the air drawn in through the perforations in the burner. In one arrangement, the steam for

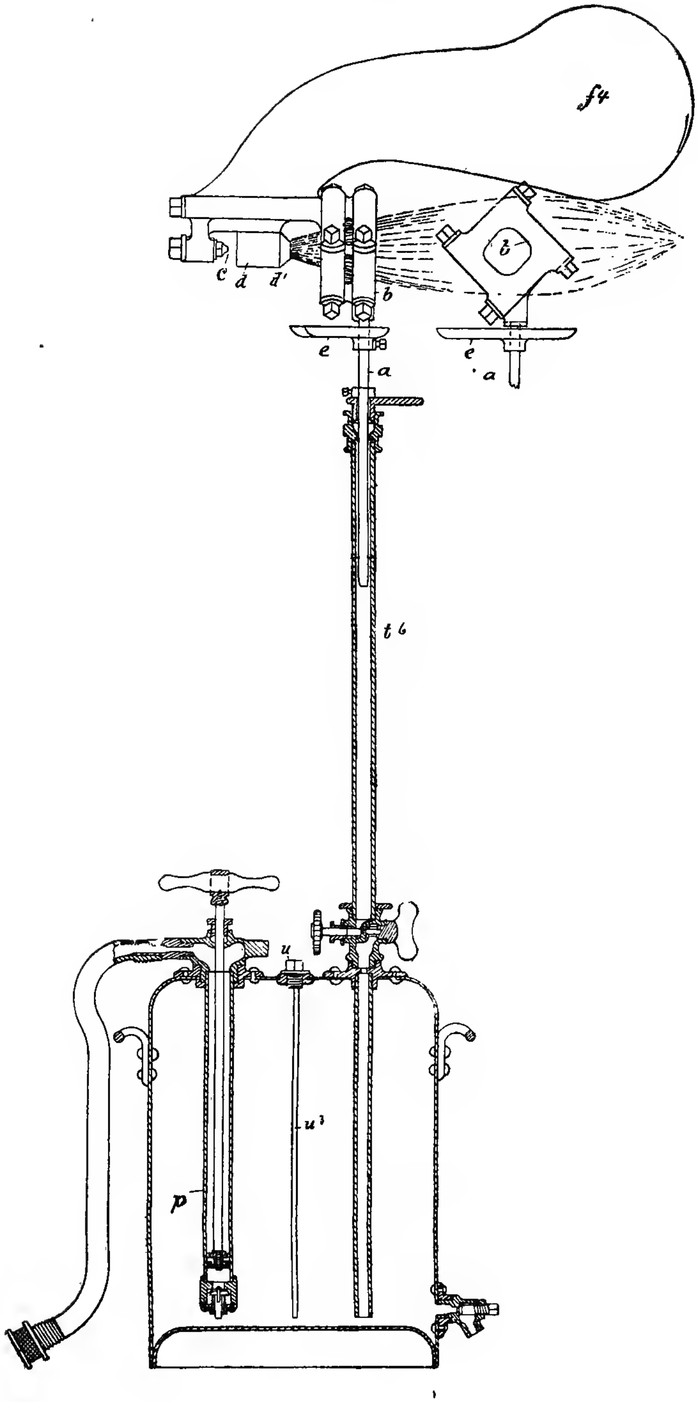
FIG. 282.



producing the blast is generated in a copper vessel on which the flame impinges. When steam is used, the oil is supplied to the burner by gravitation from a higher level, or if the reservoir cannot conveniently be placed at a sufficient elevation the oil may be raised from a tank below the burner by the pressure of steam admitted into a flexible bag within the tank.

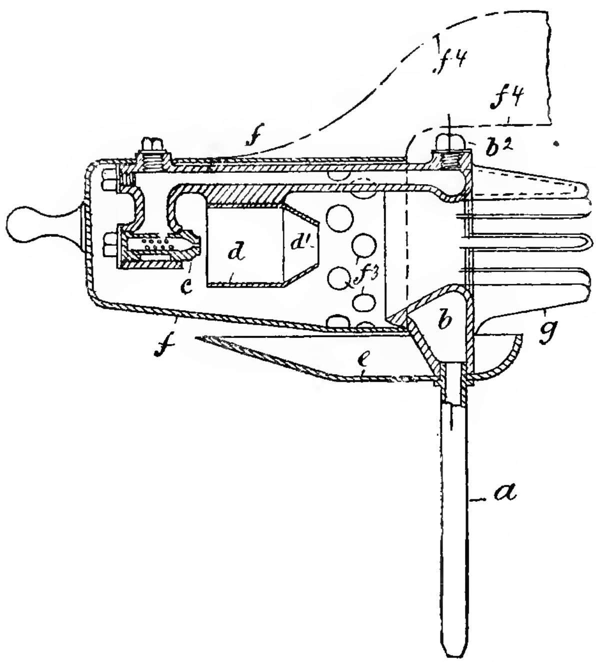
In the Wells' light, Fig. 283, patented by Wallwork and Wells (No. 2352, A.D. 1888, and Nos. 6738 and 20,366, A.D. 1889), the oil is raised to the

FIG. 283.



burner by compressed air occupying the upper part of the reservoir, or by the use of springs or weights, and is vaporised, before combustion, by the heat of the flame. The use of an air-blast is dispensed with. The reservoir is provided with a pump *p* for charging it, and with a screw plug *u*, having a vertical groove traversing its thread. Air may be admitted to the reservoir by partly unscrewing the plug. By means of a rod *u′*, attached to the plug, the height of the liquid in the reservoir may be ascertained. The burner may consist, as shown in Fig. 284, of a hollow casting *b* of annular form, which is shaped conically on the side facing the nozzle *c*, screwed into a branch of the casting. In starting the lamp, a piece of tow saturated with oil is burned in a cup *e*, to heat the burner. The oil becomes vaporised in the chamber *b*, the vapour passing out at *c*, drawing in air while travelling

FIG. 284.



through a cylinder and cone *d d′*, and burning at the mouth of the burner. The casting *b* may have projecting hollow or solid gills *g*, which become heated and assist in the vaporisation of the oil. The cover *f* of the burner is provided with air-holes f^3. The burner sometimes has a wind vane f^4, the tube *a* being arranged to turn in the supply tube t^6, Fig. 283, so that the flame shall always keep in line with the wind.

Several other arrangements of burners have been patented by these inventors. In Fig. 283, and the detached figure represented in the flame, the burner consists of a double ring casting through which the flame passes, the oil being heated in its passage through the annular spaces.

A number of blast lamps have been patented by Rose (Nos. 4504, 6333, 16,987 and 18 101, A.D. 1889). In his "Diamond" lamp, the oil tank contains a water tank from which a coil of pipe passes round the flame. The steam thus generated exerts a pressure in the water reservoir, of about 35 lbs.

on the square inch, and the oil, which flows by gravitation from the oil tank into a small well on the burner, is converted into spray without the use of compressed air. His "Beacon" lamp, designed for use in low-roofed structures, has a flame which burns vertically downwards, and the oil is raised to the burner by air compressed into the reservoir to about 25 lbs. pressure.

In the "Comet" lamp supplied by Sinclair and Co., and in the "Scott" lamp, the oil is also conveyed to the burner through the medium of air compressed into the reservoir, and is burned without an air-blast, whilst in the "Ne Plus Ultra" lamp of Kempson and Co., steam, generated by the heat of the burner, is employed for the same purpose.

CHAPTER X.

Manufacture of Oil Gas.

This important illuminating agent may be considered as the forerunner of coal gas, although its employment was almost discontinued until quite recently. The use of compressed oil gas for lighting purposes was suggested as early as 1792 by Murdock, and in 1815, Taylor of Stratford, Essex, took out a patent (No. 3929) for preparing gas from vegetable and other oils by passing them through highly heated pipes. In 1819 Gordon and Heard patented (No. 4381) a means of compressing the gas so as to render it portable. The gas prepared by Gordon was examined by Faraday, who published a paper of great interest on its bye-products ("Phil. Trans." 1825, 440).

The recent development of the industry appears to have commenced in 1871, when oil gas was introduced with marked success on the railways of Silesia. This illuminant was adopted by the Metropolitan Railway in 1876, and is now largely used both for trains and on board ships, as well as for lighting buoys, lighthouses, &c., on account of its great light-giving power and because it suffers less deterioration under compression than coal gas. For use in buoys, it is generally compressed to about 10 atmospheres. In New York and many other cities in the United States, a mixture of oil gas and water gas is very largely supplied for domestic lighting purposes, and in England oil gas has been used to a considerable extent by the Gas Light and Coke Company and other gas companies as an enricher of coal gas. In this country, oil gas has until recently been usually manufactured from a residual product obtained in the distillation of Scotch shale oil. This product, which is known as gas oil, is intermediate in respect to specific gravity and flashing point between the burning oils and lubricating oils. Latterly, an intermediate oil obtained from Russian petroleum has been employed by the gas companies as a source of gas.

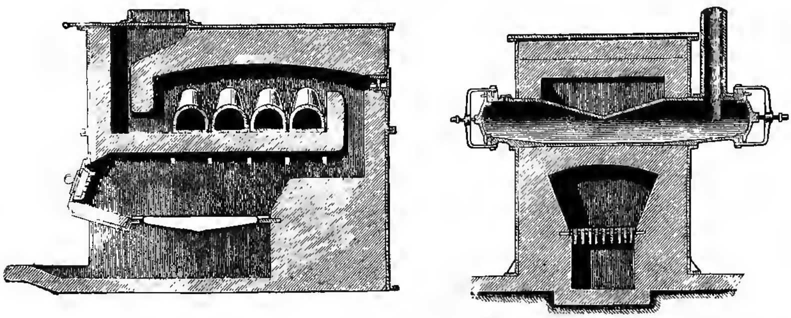
A system which has been largely adopted in making oil gas for use in buoys, lighthouses, &c., is that of Pintsch (Patents No. 3101, A.D. 1873; 4515, A.D. 1876; and 4967, A.D. 1883). The retorts, which are of cast iron and D-shaped, are heated to a bright cherry redness, and are worked in pairs, one being set above the other. The oil is run into the upper retort at one end, where it falls upon an iron tray, and the vapour thus produced passes into the lower and hotter retort where the conversion into permanent gas is completed. The gaseous product thence travels through the hydraulic main, where much of the tar is deposited. The oil gas finally

passes through a condenser and purifier into a gas-holder. About 80 cubic feet of gas per gallon of oil is considered a good yield.

In the arrangement of Pope and Sons, used by the London and North-Western Railway Company, there are also two sets of retorts, a lower set into which the oil is admitted in fine streams, and an upper set in which the products are subjected to further heating.

In the Keith plant, which is used in connection with the Langness and Ailsa Craig Lighthouses, the central portion of the retorts is constricted as shown in Fig. 285, and the oil is delivered through an inclined trough into this constricted and hottest part. One gallon of oil is said to yield from 100 to 150 cubic feet of 50 candle gas.

Fig. 285



Paterson's oil-gas apparatus is fitted with cast-iron retorts into which the oil is introduced by pipes passing through them from the front nearly to the back. The oil becomes vaporised while traversing the pipes, and is converted into gas while passing back through the retorts to the outlet at the front.

In the process of oil-gas manufacture the vaporised oil is subjected to a sufficiently high temperature to effect the conversion of the liquid hydrocarbons into a permanently gaseous product of high illuminating power, but it is important that the heat applied should not be so high as to cause the deposition of carbon from the gas. The colour of the gas at the time of production should be nut-brown and the tar separated from the gas in its passage through the hydraulic main should when dropped on white paper not exhibit a greasy margin. If the oil be supplied to the retort too abundantly, or if the temperature of the retort be insufficiently high, the gas will be light brown or white in colour, and the greasy margin referred to will be formed; whilst, on the other hand, if too little oil be passed into the retort, or if the temperature of the retort be too high, the colour of the gas will be dark brown and flakes of soot will be discernible. After passing through the hydraulic main, the gas is washed with water and purified by passing it over a mixture of slaked lime and sawdust in the proportion of two parts to one.

When compressed to 10 atmospheres, the gas loses about 20 per cent. of its illuminating power owing to the deposition of hydrocarbons, and then possesses an illuminating power of from 40 to 50 candles. The cost of the gas manufactured at Blackwall by the Trinity House authorities, is said to be about 10*s.* per thousand feet According to Thompson, the use of oil gas on the Metropolitan Railway is less costly than that of coal gas.

Oil gas is rich in ethylene, marsh gas, and crotonylene, and, according to Martius ("Berichte der deutschen chem.Gesellschaft," i. p. 88), frequently contains a considerable amount of acetylene. Armstrong and Miller, however,

do not confirm this. The tar obtained in the manufacture amounts to about 5 gallons per 1000 feet of gas, and is usually burned under the retorts.

The liquid obtained by the compression of the gas is exported to Belgium, where it is said to be used as a solvent in the manufacture of varnish. It contains from 24 to 65 per cent. of benzene and toluene (Greville Williams, "Chem. News," xlix. 197), but is practically free from paraffin. Its employment in the carburetting of water gas and air has been proposed, the strong characteristic odour of the gaseous illuminant thus produced being of advantage in respect to the detection of leakage.

For further information regarding the manufacture and nature of oil gas, see Ayres ("Proc. Inst. C.E.," xciii. 298–363), Armstrong ("Jour. Soc. Chem. Ind.," 1884, 462), Armstrong and Miller ("Jour. Chem. Soc.," 1886, 74), Kuchler's "Handb. der Mineraloel-Gas-beleuchtung und der Gas-bereitungsoele," Lewes ("Journal of Gas Lighting," &c., 1891, vol. lvii. 1182); and "Cantor Lectures of the Society of Arts," 1890, Macadam ("Jour. Soc. Chem. Ind.," 1887, 199), Rowan (*ibid.* 1888, 195).

Practical experience has demonstrated that with a view to the production of a permanent gas suitable for use in the enriching of coal gas, the dissociation of mineral oils can be most advantageously effected by the heating of the vapour in admixture with a gaseous vehicle such as water gas. The Springer, Lowe, and other processes largely employed in the United States, and already adopted to some extent in this country, are based upon this principle, but the consideration of these processes lies outside the scope of this article.

CHAPTER XI.

Air-gas Machines and Carburettors.

AIR gas, which is largely used in the United States and elsewhere, consists of an inflammable mixture of air and the vapour of volatile liquid hydrocarbons, such as the lighter descriptions of petroleum spirit known as gasoline. The proportion of the vapour which air is capable of taking up varies with the temperature and with the nature of the carburetting material used. Air is stated to retain of the vapour of gasoline (sp. gr. 0.650) 5.7 per cent. at 14° F., 10.7 per cent. at 32° F., 17.5 per cent. at 50° F., and 27.0 per cent. at 68° F.

Letheby ("Jour. Soc. Arts," x. 87) stated in 1861 that the carburetting of coal gas with 10 grains of volatile hydrocarbons per cubic foot resulted in an economy of from 40 to 50 per cent. Air charged with 735 grains of gasoline per cubic foot has been found to possess an illuminating power of 16.5 candles when consumed at the rate of 3½ cubic feet per hour in a 15-hole Argand burner.

The carburetting of illuminating gas or air appears to have been first proposed in 1831 (Patent No. 6179) by Lowe, who in 1841 obtained a patent (No. 8883) for a carburetting process. Mansfield ("Jour. Soc. Arts," ii. 520) and Longbottom ("Jahresbericht," 1856, 422), also proposed methods of carburetting air. The carburetting of coal gas by the introduction of the vapour of volatile hydrocarbons is now carried on to a considerable extent by gas companies in this country, as it affords a ready means of increasing the illuminating power of the product at the time of delivery from the gas-holder.

Air gas making machines are usually constructed on the principle of

passing air over a considerable surface of gasoline, the requisite area being in some cases obtained by the use of curtains of flannel suspended in the carburetting chamber with their lower edges dipping into a reservoir of the fluid.

The chief difficulties experienced in the use of such machines arise from over-saturation of the air in warm weather or when the apparatus is first charged, and reduction in the temperature of the gasoline by evaporation. These difficulties have been to a great extent overcome by immersing the carburetting chamber in a tank of water and placing the whole apparatus below ground.

Even under these circumstances, however, fractional evaporation occurs, and a residue of insufficiently volatile spirit remains after the apparatus has been for some time in use. With a view of overcoming this objection to the process, an apparatus termed a "metrical carburettor" has been introduced by an American inventor of the name of Jackson. This machine is so constructed that a measured quantity of the gasoline is delivered to the gas or air passing through it, the proportion recommended being 1½ to 2 gallons per 1000 cubic feet in the case of gas and 3 to 6 gallons (according to the illuminating power required) in the case of air.

Müller's "Alpha" gas-making machine, Fig. 286 (p. 328), consists of a rectangular carburettor or chamber containing a number of shallow trays over which gasoline is caused to flow. In connection with the carburettor is a revolving blower driven by a weight, a weighted lever being added to keep the drum revolving while the cord which sustains the weight is being re-wound on the drum. The air is driven by the blower over the surface of the gasoline and is thus carburetted.

Several patents for air-gas generators and for lamps in the body of which air is carburetted for immediate consumption, have been taken out by Hearson and Kidd, the latter in some cases in conjunction with Livesey. Among these may be mentioned Hearson's "auto-pneumatic" gas machine and Kidd's machine (Patent No. 1917, A.D. 1873). In the latter, Fig. 287 (p. 329), the gasoline is driven from a reservoir into which air has been forced by a pump to a pressure of 10–30 lbs. per square inch, through a pipe into a boiler surrounded by an outer casing containing water heated by a gas flame. The vapour generated passes intermittently under pressure through a jet, and becomes mixed with air which is drawn in through a valve fitted with an adjustable socket to regulate the amount entering. The mixed air and vapour pass to the gas-holder, which is fitted with an automatic arrangement for cutting off the supply of hydrocarbon vapour when it is full.

Fig. 288 shows Lothammer's air-gas machine. The air supplied at a constant pressure at *A*, passes from the outer casing of the apparatus through an arrangement of check valves *O*, in chambers *P*, into a tube *E*, terminating in a number of small flattened tubes *I*. These tubes are so arranged as to cause the air which issues from them to bubble through gasoline in an inner chamber *G*, supplied from a reservoir *g*, through a pipe *F*. The gas is withdrawn for use through a pipe *M*. A coil of pipe *t*, through which air which has been heated by a flame is caused to pass, may be employed to prevent excessive cooling of the liquid by evaporation. An adjustable weighted balance valve *S* regulates the pressure according to the number of burners in use and their distance from the generator, any excess of air supplied at *A* escaping directly from the vessel *C* at the valve, before being carburetted.

Among the large number of other inventions introduced for enriching coal gas and carburetting water gas or air by means of the vapour of mineral spirit, the limits of this article only permit mention of the following.

FIG. 286.

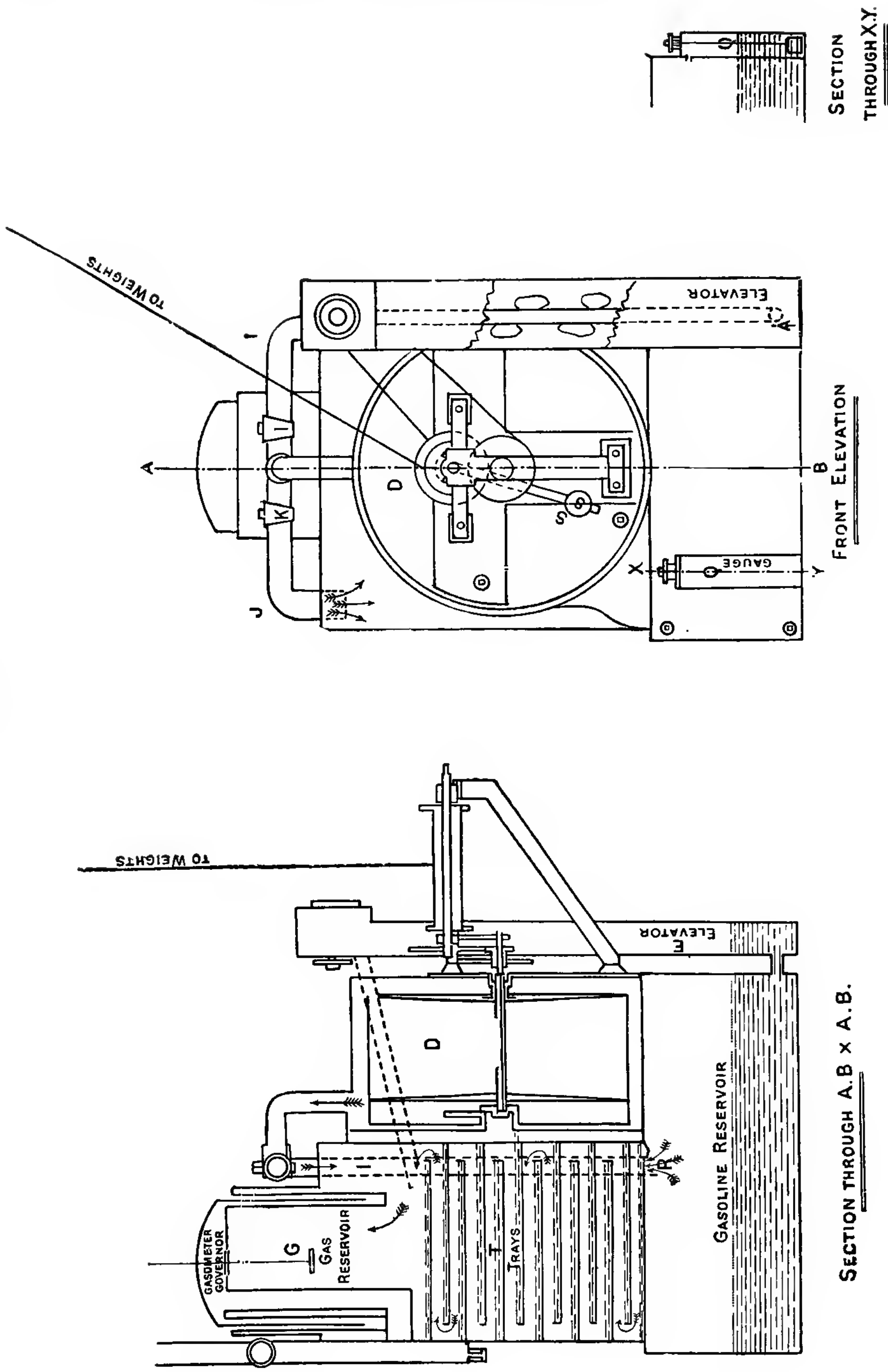
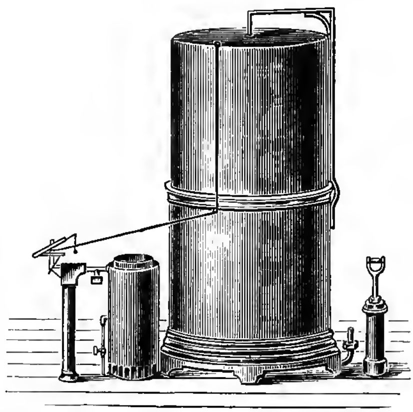

SECTION THROUGH X.Y.
TO WEIGHTS
ELEVATOR
A
B
D
S
I
K
J
X
Y
GAUGE
FRONT ELEVATION
TO WEIGHTS
ELEVATOR
E
D
R
GASOMETER GOVERNOR
G
GAS RESERVOIR
T
TRAYS
GASOLINE RESERVOIR
SECTION THROUGH A.B × A.B.

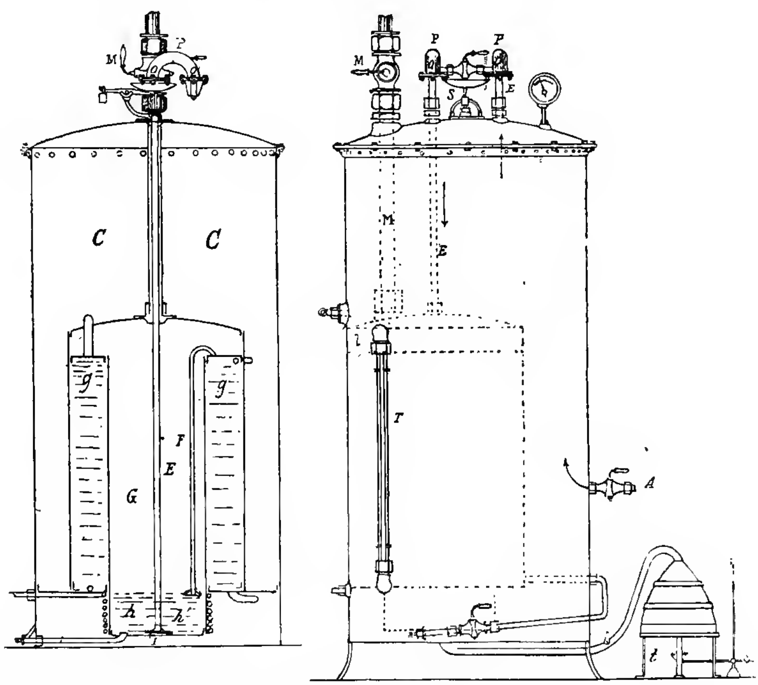
Fig. 289 represents Weston's carburettor (Patents No. 3301, A.D. 1875, and No. 3865, A.D. 1880). It consists of a reservoir *A* and a carburetting

FIG. 287.



chamber *B*, which is supplied therefrom with liquid hydrocarbons, a constant level of the spirit being maintained. The chamber *B* is fitted with curved plates dividing it into annular chambers so that the gas entering at *D*

FIG. 288.

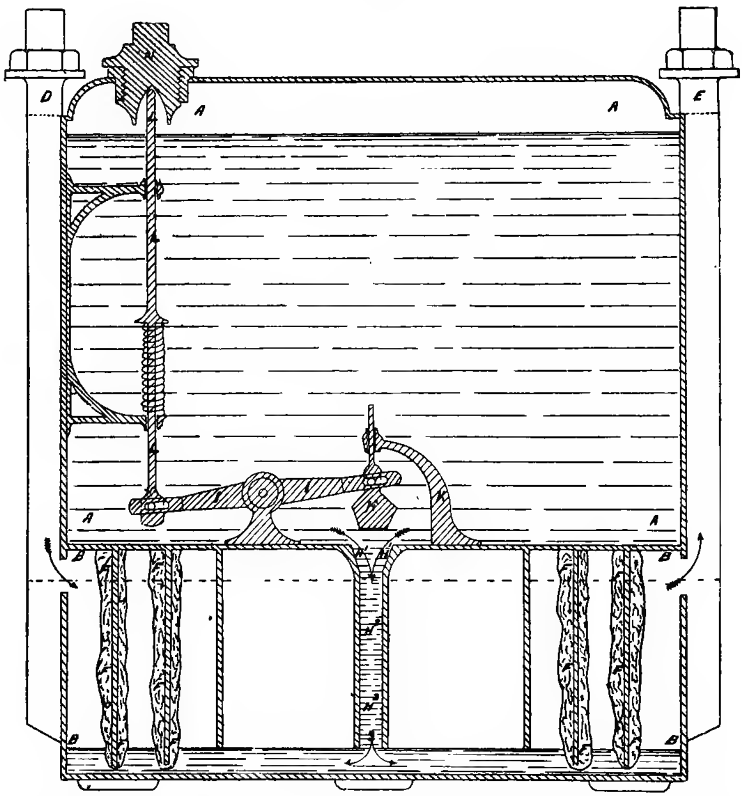


passes through a tortuous path before its discharge at *E*. The plates are surrounded by spongy or fibrous matter *F* dipping into the liquid, a large surface for evaporation being thus exposed to the gas. A valve *H* is

arranged to disconnect the two chambers when the plug N is removed for charging the chamber A.

In the Maxim carburettor (Patents Nos. 703 and 2508, A.D. 1889), the illuminant—preferably gasoline—is evaporated under the action of heat, so that fractional evaporation or any alteration in the rate of volatilisation due to variations in the temperature of the air is prevented, and the amount of gasoline vapour introduced into the gas or air is automatically adjusted according to the rate of consumption of the product. Experiments with coal gas show that in this apparatus the gas is carburetted to an extent which is practically the same whether a large or small number of

FIG. 289.

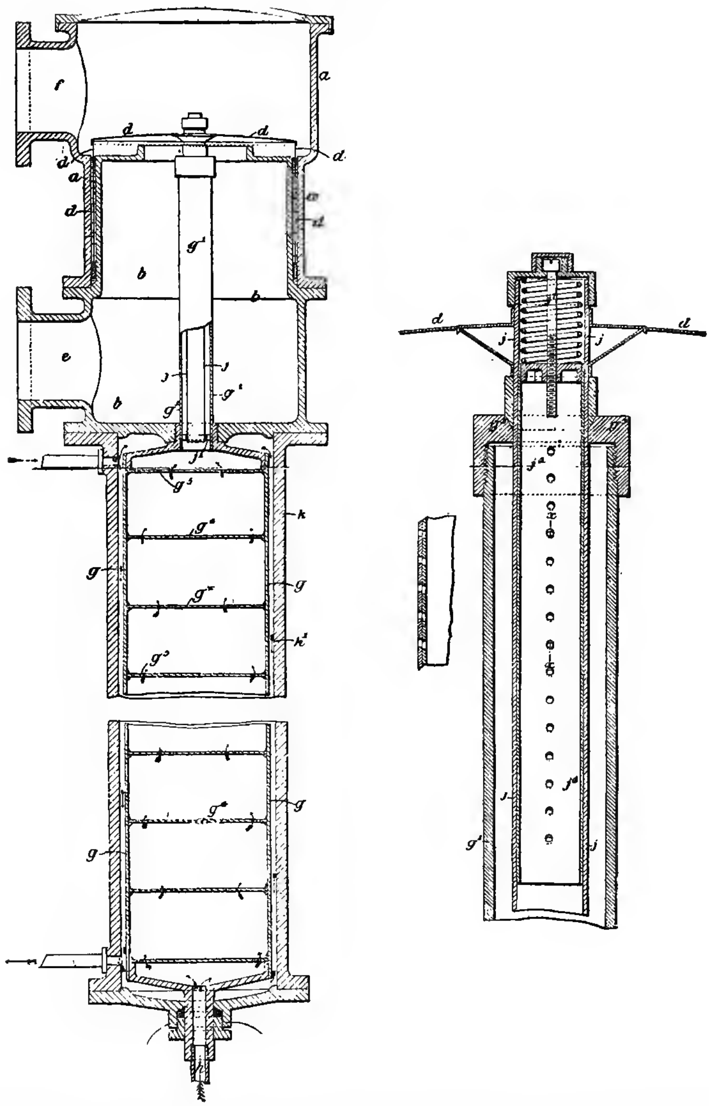


burners is supplied, and that the carburetted gas deposits no liquid when cooled to 10° C. (50° F.).

In Maxim's improved apparatus, Fig. 290, the gas to be enriched is supplied at e to a mixing chamber b surmounted by a gas-holder d, which rises and falls in mercury contained between the chamber b and the outer casing constituting the lower part of the chamber a. The gas-holder has perforations in the proper position and of a regulated size, so that when it rises to a certain height the gas is delivered to the upper part of the chamber a, and passes away at f. The gasoline is supplied at h from a distant reservoir at a suitable level, to a chamber g heated by steam or by hot air from a ring burner surrounding its lower part, and strengthened by internal plates g^4 having perforations so arranged as to

ensure circulation of the liquid as shown by the arrows. The vessel g terminates in a tube g^1, through the cap of which slides a tube j fixed to the gas-holder and having a series of apertures. As the gas-holder rises or falls, a greater or less number of these apertures are above the cap, so

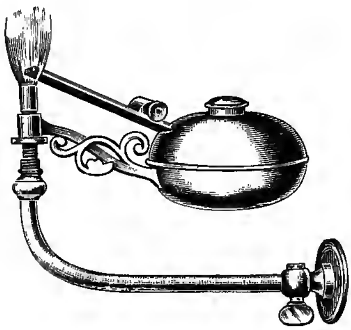
FIG. 290.



that more or less of the gasoline vapour is allowed to mix with the gas in the holder, according to the rate of consumption. To provide further regulation, the tube j may be fitted with an interior tube j similarly perforated and admitting of longitudinal or angular adjustment, so that the openings may be brought more or less into coincidence to vary as required the quantity of vapour passing through them.

In another arrangement, the tubes jj^4 are dispensed with, and the gas-holder carries a rod which passes through the cap of the tube g^1 and has tapering V-shaped grooves which permit passage of more or less vapour into the holder in proportion to the width of the channel which is above the cap.

FIG. 291.



Weston's "Omega" lamp (Patent No. 810, A.D. 1874), in which coal gas is carburetted by means of hydrocarbon vapour, is arranged similarly to his carburettor previously described. The lamp reservoir is divided into an upper and a lower section by a partition, the upper division holding the gasoline and the lower containing sponge or other absorbent material saturated with the liquid, a large surface for evaporation being thus provided. The lower chamber is supplied with spirit from the upper one through a valve, the desired level being maintained by the action of a float lying on the surface of the liquid. The gas to be enriched passes through the lower chamber and thence to the burner.

Fig. 291 shows a coal-gas carburettor introduced by Spong (Patent No. 2664, A.D. 1889). It is furnished with a reservoir charged with ordinary petroleum oil, and is attached to the gas-burner in the manner illustrated. The oil is carried to the flame by an adjustable wick.

CHAPTER XII.

Ships' Lights, and Railway Carriage Roof Lamps.

THESE lamps differ from those employed for other purposes principally in the arrangements adopted to prevent extinction of the flame by wind or water.

FIG. 292.

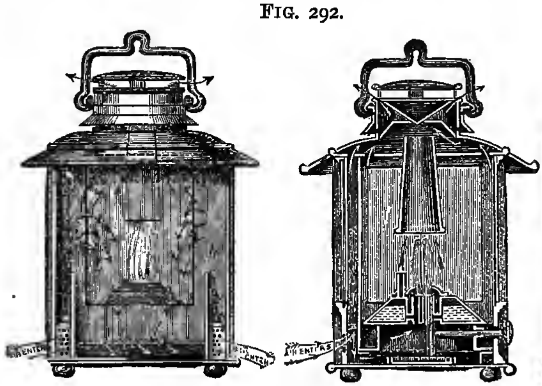
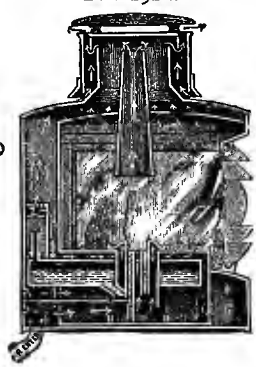


FIG. 292*a*.



The two illustrations in Fig. 292 represent one form of the Silber lantern which is employed for ships' side and masthead lights. The necessary draught is produced by a tapering metal chimney, and the reservoir is

arranged in the compact form shown, an external milled head permitting adjustment of the wick (which is required about once in six hours) without opening the lantern. The air for supporting the combustion enters a chamber formed between two vertical plates at the back of the lantern, through two vertical tubes about one-third the height of the chamber and half an inch or more in diameter. The tubes are fitted with wire gauze at their lower ends with the object of breaking up the air-current. The air passes up the chamber with a velocity depending on the force of the wind,

Fig. 293.

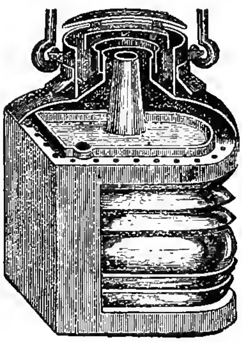


Fig. 294.

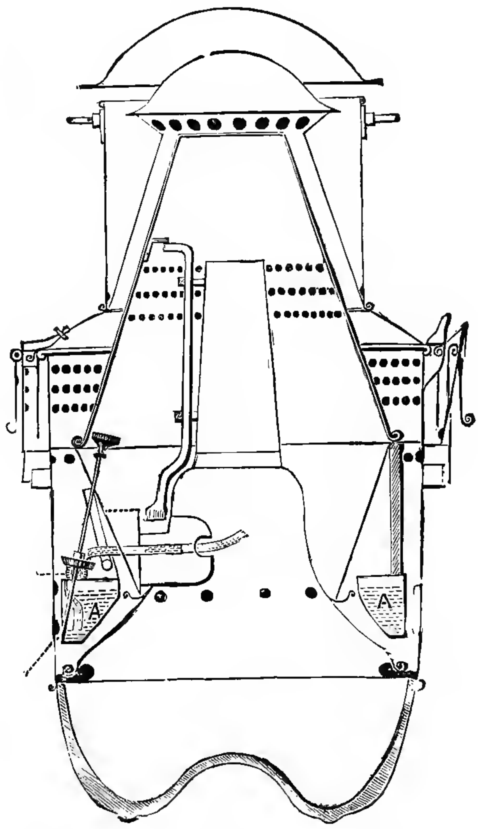
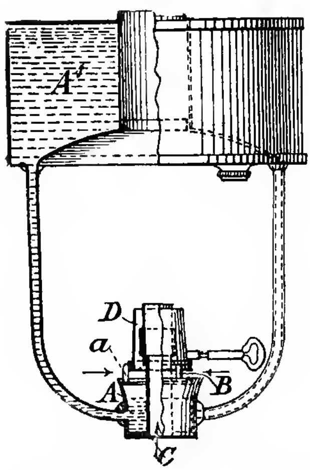


Fig. 295.



and having become somewhat heated, descends less rapidly to the lower part of the lantern, whence it rises slowly and feeds the flame, as shown in the figure.

To permit the escape of the products of combustion without allowing entrance of wind or water, the issuing current is directed by the action of the chimney against an inverted cone surmounted by a plate. The gases thus pass out round the edge of the cone, while water is excluded. Any wind or strong air-current sweeping between the plate and the cone assists rather than impedes the action of the lamp, by improving the draught.

The lamp depicted in Fig. 292 *a* has a modified top, the cone being

replaced by a flat flanged cover which directs any downward air-currents or water through an open tube surrounding the upper part of the lantern.

To provide for an excessive inflow of water such as may occur through the breaking of a wave, an outlet tube may be fitted through the body of the lantern as shown in Fig. 293, and a metal ridge may be added to direct any entering water towards the tube.

The oil-container and lens are kept cool by allowing a portion of the air which enters the lamp topass over the container, and to travel upwards between the lens and the flame. The heat of the flame is stated to be even then always sufficient to prevent the congealing of the oil, which has been known to occur in some forms of masthead lights. Colza oil is used in these lamps in preference to petroleum.

Fig. 294 represents a lamp introduced by Silber as a railway carriage roof lamp. The oil reservoir A is annular, and is placed below the horizontal wick. The air for supporting the combustion passes through perforations in the outer casing, a considerable portion being caused to travel over the reservoir to keep it cool. After circulating round the exterior of the combustion chamber, it passes down through a perforated grid into the burner dome, whence it issues round the flame. The combustion chamber at the base of the chimney is lined with white enamel, and is shaped to act as a diverging reflector, so as to distribute the light downwards.

Fig. 295 shows a railway carriage roof lamp introduced by Aria (Patent No. 15,768, A.D. 1888), for burning ordinary petroleum oil. An upper reservoir A' supplies the oil to a small chamber A, having an inwardly-turned lip a, which prevents spilling in case of a sudden shock. The detachable wick case D is carried by a skeleton frame B secured to the lip a, and a tube C passing through or replacing the inner tube of the wick case, allows passage of air to cool the chamber A and support combustion. The base of the reservoir A' serves as a reflector.

Circular-wick lamps for railway carriages, ships' signal lights, &c., have also been introduced by Ridsdale (Patents Nos. 1524, 1620, 2420, A.D. 1872).

SECTION VI.

MINERS' SAFETY LAMPS.

BY

BOVERTON REDWOOD AND D. A. LOUIS.

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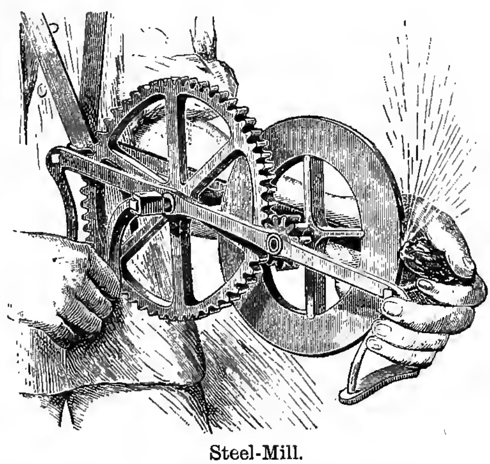
1. Early History of Safety Lamps.

ORDINARY candles or lamps of the simplest construction serve for the lighting of most metalliferous mines and some coal mines, but in the large majority of the latter the use of such appliances for lighting purposes is attended with very great risk. In fact, for a considerable number of years, mines wherein the conditions were such as to prevent the employment of naked flames were necessarily left unworked for want of a safe means of lighting.

The first step in the direction of providing a safe light for use in an explosive or inflammable atmosphere was taken by Spedding, who, in 1760, introduced the steel-mill, Fig. 296. This contrivance consisted, as will be seen from the illustration, of a steel disc mounted on a horizontal axis carrying a pinion, which could be rotated by a large spur-wheel also mounted on a horizontal axis, and provided with a cranked handle. In the use of the apparatus the steel disc was caused to revolve rapidly, and a piece of flint being brought into contact with it, a shower of sparks was produced. The light thus furnished was both feeble and fitful; moreover, it was not safe.* Men of science and practical experience therefore began to give attention to the problem of preventing the lamentable loss of life constantly resulting from explosions in coal mines, by providing an efficient and safe means of illumination.

FIG. 296.



Steel-Mill.

* It is worthy of note, that whilst a spark produced with flint and steel appears to be capable of causing the ignition of an explosive mixture of fire-damp and air, the results of some experiments made by Dr. Dupré and by one of the writers for the information of Her Majesty's Chief Inspector of Explosives, indicated that an explosive mixture of petroleum vapour and air could not be ignited by an ordinary spark.

Humboldt was the first to suggest, in 1796, the use of a safety lamp as a substitute for the steel-mill, but his lamp was not of convenient construction, and moreover its use was not unattended by risk. Various other attempts and failures, with concomitant disasters, led to the subject being thoroughly and scientifically investigated, and at length the results of Davy's classical researches were presented to the world. It had long been known that the combustible gas emanating from coal, produced, in admixture with the air in the mine, an atmosphere which exploded when a light was brought into contact with it; but Davy was not satisfied with this general knowledge, and accordingly ascertained by experimental investigation the conditions under which such explosions took place. He found the principal condition to be that the proportion of combustible gas in the air of the mine must be not less than 7 per cent. nor more than 16 per cent. Below or above these proportions, the mixture is either not inflammable or else it burns more or less quietly and without explosion. The second important condition is that there must be a high temperature for the ignition of even a very explosive mixture, actual flame or a temperature above that of a bright red heat being needed. Thirdly, it was found that the presence of other foreign gases has the effect of modifying the conditions, usually in the direction of decreasing the risk or diminishing the violence of the explosion.

The proportion of inflammable gas in the atmosphere of a coal mine cannot be controlled or regulated by any system of ventilation, for the simple reason that the gas is seldom evolved uniformly, but more frequently is given off in irregular outbursts. These occur at times when the coal is broken down and, generally, when attacking new ground; an emission of gas also often takes place when the barometer falls, the diminution in atmospheric pressure permitting its escape from accumulations in waste heaps and vacant spaces in the mine. Good ventilation obviously lessens the chance of explosion by rapidly reducing the proportion of combustible gas below the dangerous minimum. Further information on this point will be found in Vol. I., "Fuel" (p. 59 *et seq.*).

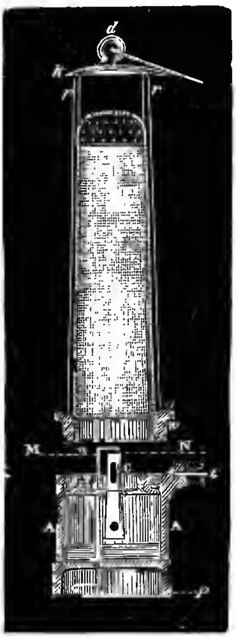
Davy's further researches had reference to the second condition specified —namely, that of the existence of a sufficiently high temperature. It had been demonstrated that heated gases were effectively cooled by being passed through metal tubes of small diameter, but to Davy is due the invaluable discovery that gauze constructed of wire of a diameter proportionate to the intervening spaces, is equivalent to *sections of tubes*, as he expressed it, and performs all the cooling functions of the tubes themselves. Putting this discovery into practice, the safety lamp, see Figs. 297, 298, 299, and 300, the introduction of which has largely contributed to render the name of Davy illustrious, and has entitled him to the gratitude of mankind, was constructed in 1815.

The Davy lamp, of which Fig. 297 is a section, whilst Figs. 298 and 299 show the details, will be seen to consist of three distinct parts—namely, the lower portion or base, forming a reservoir for oil; the body, or circular envelope of wire gauze impermeable to the flame; and the exterior brass framework. The oil cistern A A is a cylindrical metal box, the upper surface of which is formed of a copper or brass plate with a circular opening in the centre. A ring screws into this opening, rising slightly above the surface, Fig. 299. The socket which supports the wick, Fig. 298, consists of a circular plate *a b*, attached to a vertical tube *c*. This tube has a long lateral opening, into which a piece of bent wire terminating in a hook *n*, and known as the "pricker," is made to pass so as to enable the miner to adjust the wick without opening the lamp; the hook, or pricker, accurately fits a tube passing through the oil cistern, and its lower end, which forms a handle, is guarded by the ring *p*, forming the base of the lamp.

The wire gauze chimney or cylinder was commonly about 6 inches long and $1\frac{1}{2}$ inch diameter. A cylinder of greater diameter being objectionable, as it is capable of enclosing a larger volume of inflammable gas in a state of combustion, the gauze being thus liable to be more quickly raised to a red heat, with the result of destroying its texture. In accordance with the principle already enunciated as to the relation of the holes to the wire of the gauze, the standard fixed as a limit for safety was, and still is, a gauze of 28 iron wires to the linear inch, having 784 openings per square inch, but gauze of smaller mesh is frequently used.

The frame was constructed of three or four strong metal rods *r r* attached to an upper plate of metal *k*, to protect the miner's hand from the heat of the flame and the lamp from water dropping from the roof of the mine, and to a circular ring *o* at the bottom, fitted with a screw *w* for fixing on the oil cistern.

FIG. 297.

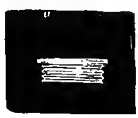


Davy.

FIG. 298.

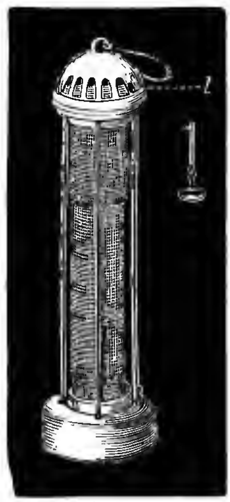
Davy.

FIG. 299.



Davy.

FIG. 300.



Davy.

A ring *d* was attached to the plate *k*, by which the lamp could be carried or suspended in any convenient place.

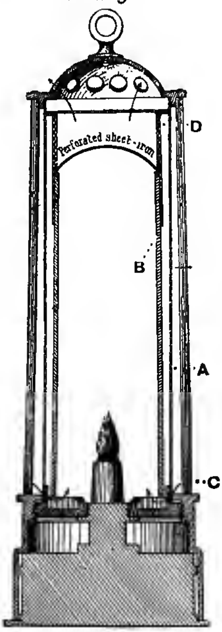
The cylinder could be further secured to the oil cistern by the lock *e*. Various contrivances had been proposed by Regnier and others to render this more secure, and one once very generally adopted is shown at *l*, Fig. 300. It consisted of an ordinary lock, but required a long key to pass across the top of the lamp.

The upper portion of the lamp was made of a double sheet of wire gauze, or in some localities of perforated sheet copper, to better resist the corrosion and consequent destruction caused by constant contact, at such a high temperature as the interior of the lamp acquired, with the aqueous vapour, formed during the combustion.

Davy also proposed to employ a coil of fine platinum wire round the flame, so that, in the event of its being extinguished, there might still exist ufficient illumination for the miner; this, however, failed in practice.

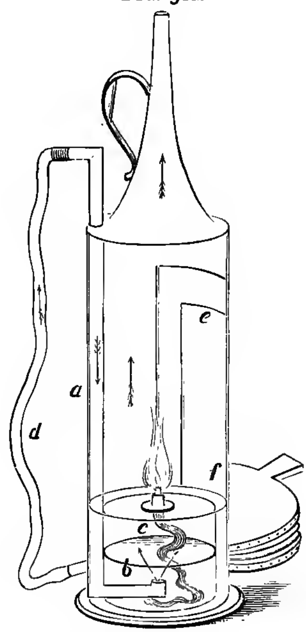
Another of our distinguished countrymen, George Stephenson, had also been devoting his abilities to this important subject, with the result that he introduced a safety lamp independently of Davy's lamp, but at about the time that the latter appeared. Stephenson's lamp, the "Geordie" as it was called, which is shown in section in Fig. 301, was provided at first with a perforated metal, but afterwards with a wire gauze cylinder A, about $2\frac{1}{4}$ inches in diameter and $5\frac{1}{4}$ to 6 inches high, with a glass shield B inside. The air for combustion was supplied through a triple circle of small perforations in a metal cylinder C below the gauze and glass, but above the oil vessel, which when screwed on protected them from external injury; the air therefore, in this lamp, reached the flame a little below the level of the wick. A metal chimney D, full of small holes, was fixed on the top of the glass cylinder and inside the gauze cylinder.

FIG. 301.



Stephenson.

FIG. 302.

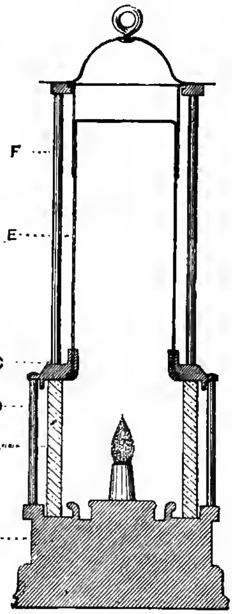


Old Clanny.

In 1813, just previous to the inventions of Davy and Stephenson, Dr. Clanny, who was unwearied in his exertions in this cause, invented lamps which burnt safely in a fiery atmosphere. Fig. 302 is a drawing of one of them, which is given more for the sake of illustrating the progress of investigation in this branch of applied science than because of any practical utility it possessed. The air was forced from bellows through a flexible tube *d* down the pipe *a*, and rose at *b* through the oil, then penetrating a perforated top plate *f* it reached the burner *c*. The arrows, as in subsequent Figs., indicate the course of the air. The metallic casing was provided with a curved pane of glass *e*, and terminated above in a chimney. By this arrangement flame was prevented by the intervening layer of oil from passing back from the interior of the lamp to the external air; in earlier forms water was used for the same purpose, and not alone did the air supply bubble through this liquid, but also the products of combustion. The arrangement was, however, far too inconvenient and unpractical to be of any use for mine illumination.

Subsequently Dr. Clanny modified his lamp considerably; it was constructed without bellows and accessories, but with an impervious metal shield, having glass and lenses in its sides, only open at the highest part of an internal gauze cylinder for about 1½ inch from the top, and surrounding the lamp entirely down to the oil vessel, the shield being in diameter fully half an inch more than the lamp. There was consequently admission or egress of air *only over the top of the shield* at the highest part of the lamp. The light from this lamp was too feeble for practical purposes, but Dr. Clanny obviated this by placing opposite the flame a thick globular shield of glass, which was found to reflect the light in a very perfect manner. Ultimately Clanny's lamp assumed the more practical and neater form shown in Fig. 303; in it, the glass shield B is reduced in height so as to simply surround the flame, but still rests on the oil vessel A, and to protect it and keep it in position the frame is provided with the short brass rods D, and the intermediate brass ring C, which supports the gauze E, and the upper part of the frame F. Hence, only the upper part of the lamp is protected by gauze; nevertheless the air had still to enter through the gauze above the glass cylinder and to descend to supply the flame.

FIG. 303.*



New Clanny.

This last model of Clanny lamp, with the Davy and Stephenson, furnish the three original types of safety lamps, from which have sprung the numerous and varied forms introduced from time to time.

It is remarkable that the wire gauze surrounding the flame not only cools the gases in the event of their being ignited within the lamp, and so prevents the communication of flame to an explosive mixture outside, but also tends to prevent the occurrence of explosions inside the gauze cylinder, in accordance with the third of the conditions already set forth (p. 336), inasmuch as the air surrounding the flame becomes mixed with carbonic anhydride and other products of combustion, as well as with some inflammable vapour which has escaped combustion. Consequently any explosive gaseous mixture passing into the lamp becomes considerably altered in composition before it reaches the flame, so that its sensitiveness to ignition is reduced from this cause, and combustion is not rapidly propagated through it.

Another important and notable feature of this kind of lamp is that it acts as an indicator of the presence of "fire-damp," as the inflammable gas of coal mines is called. A slight increase in the volume and length of the flame attests the first appearance of gas, or sometimes a "cap" is formed round the flame, of which more will be said later on. The cylinder becomes filled with a light bluish flame as soon as the gas increases to between 8 and 9 per cent. of the mixture. When the proportion reaches 16 to 20 per cent. the flame of the wick disappears, being absorbed by that filling the cylinder, and ultimately becomes extinguished when the proportion amounts to one-third.

* In the sectional figures in this article, thin broken lines represent gauze, thin continuous lines sheet metal, whilst glass, brass, &c., are depicted in the manner shown in this illustration. The construction of the oil vessel, &c., being the same in most lamps, it has not been considered necessary to show or to give details in each case.

2. Safety Lamp Desiderata

Before proceeding to describe the various forms of safety lamps which have since been introduced, it will perhaps be well to indicate what their requisite features should be, and to point out the conditions which have to be observed to ensure safety in their use. The best source of information on these points is the Report of the Royal Commission appointed to inquire into Accidents in Mines, and the following statement of requirements is largely compiled therefrom.

1. The source of light within a safety lamp should be incapable, under any circumstances at all likely to occur in working coal, of causing the ignition of an inflammable mixture of fire-damp and air, even when this is travelling at a high velocity.

2. The lamp should yield, during an ordinary working day, a sufficiently bright and steady light, even when exposed to a strong current of air.

It follows from these two primary requisites for efficiency that a high illuminating power cannot be expected of a really safe lamp in which the source of light is a flame fed by air admitted into the lamp direct from that which is circulating in the mine; inasmuch as for safety the ingress of air must be impeded and the escape of highly heated products of combustion retarded, whilst for good illumination, on the other hand, free access of air to the flame and ready escape for the gaseous products are needed.

3. The lamp should be of simple construction, inasmuch as a lamp of complicated design may, in the hurry of preparing a large number for use, be imperfectly put together; and however safe when in good order, such a lamp may be most unsafe when the parts are not properly adjusted.

4. It should admit of easy and thorough inspection when ready for use, otherwise imperfections may be overlooked.

5. It should not be liable to be extinguished when handled with ordinary care, because extinguishing necessitates re-lighting and consequent waste of time in finding a safe place in which to do it.

6. It should indicate distinctly to the miner, by changes in the appearance of the flame, or by the formation of a "cap," the presence of a dangerous quantity of fire-damp in the air; and as a gaseous mixture giving a very faint "cap" becomes by the addition of 2.5 per cent. of marsh-gas converted into one which will readily explode, all lamps should be extinguished when the gaseous mixture becomes ignited inside the gauze. Therefore—

7. The construction of the lamp should be such as to admit of this extinguishing being effected either automatically, or with certainty and safety by the miner. On this account, appliances for stopping the supply of air to the flame are of great advantage if they are simple and not liable to come into operation by accident.

It may further be noted—

8. That the gauze will withstand the action of burning gas for a longer period in a tranquil than in a moving atmosphere.

9. That, if the lamp is plunged into a mixture barely inflammable, the wire gauze becomes red hot, although it remains unchanged in an explosive mixture.

10. That the safety of a lamp diminishes as the diameter of the cylinder increases.

11. That fire-damp, being relatively lighter than air, is found more abundantly near the roof of a gallery or working; hence it is important to have a lamp constructed so that air from near the roof may be allowed to reach the flame when required for testing purposes.

Moreover, the lamp should not be too heavy. No one can realise the full force of the objection to a heavy lamp without having carried one in the

hand for several hours while traversing mine workings, often through narrow passages and in the most awkward posture. The following table shows the weight of some lamps in the Museum of Practical Geology, Jermyn Street, London. Various makes of the same lamp, however, will differ in weight.

	lb.	oz.
Davy	1	6
Clanny's Improved	2	6
Stephenson's Improved	2	3½
Gray	3	1
Hepplewhite-Gray	3	2
Mueseler	2	11
Bonneted Mueseler	2	13½
Deflector Mueseler	3	9
Bonneted Marsaut	2	13
Deflector Marsaut	3	12
Thorneburry	3	13

It will now be convenient to consider how far the three original types of safety lamps fulfilled these conditions. We find that they were strong, simple in construction, and not of great weight, but they failed in respect to the first two conditions. In fact, Davy himself ascertained that a stream of air or gas would drive the flame through the gauze. In Davy's time, however, ventilation currents rarely attained a velocity of 5 feet per second, even in the main air-ways, and the movements of the air were very slow in the working places. At the present time, ventilation has improved to such an extent that currents of 20 to 25 feet per second velocity are common in the main air-ways, whilst the rate varies from 5 to 15 feet per second in the working places. Moreover, under certain circumstances—for instance, when an opening is made between two main air-ways—currents with velocities of 30 to 35 feet per second are temporarily encountered. These are liable to strike the lamps obliquely and form eddies round them; they thus become particularly dangerous if much fire-damp is present. In the words of the Report of the Royal Commission, already referred to:—"It results then from the improved ventilation of mines, that if the current becomes sufficiently charged with fire-damp, the Davy and Clanny lamps cease to be in any way safety lamps, and the Stephenson ('Geordie') lamp may often cause an explosion."

3. Description of some of the more important Safety Lamps.

Some of the more important lamps will now be described, and others which are of interest or possess merit will be mentioned; but no attempt will be made to embody every suggestion which has been put forward in connection with the subject, since this would extend the article far beyond reasonable limits, without affording useful information to the reader. In order to facilitate comparison, the lamps will not be introduced chronologically, but will as far as possible be classified on the basis of their resemblance to one or more of the original types already referred to—namely, the Davy, in which the air supplied to the flame freely passes through any part of the gauze envelope; the Stephenson, in which this air enters the lamp and also arrives at the flame below the wick; and the Clanny, in which air enters the lamp and reaches the flame from above.

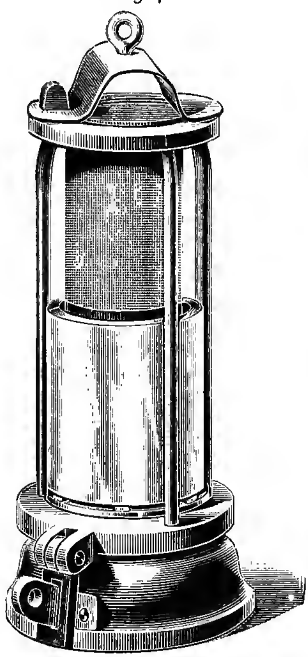
Commencing with the Davy; the original lamp, two specimens of which are preserved in the Museum of Practical Geology, Jermyn Street, London, and others in the Wood Memorial Hall, Newcastle-upon-Tyne, from its small size, its very fine gauze, and its feeble flame, was soon found wanting in many respects. The light was bad and not lasting, the gauze soon became useless, and numerous accidents occurred. Consequently modifications were introduced in respect to the size and height of the lamp and description of gauze

employed. The depth of the gauze cap ("smoke gauze"), and the extent to which it overlapped the main gauze, were also both increased. Ultimately, by employing the coarsest gauze consistent with safety, a fairly good lamp was obtained; but still it was defective, the least increase in the speed of the air current caused it to flicker, and, what was far worse, drove the flame through the gauze just at the most dangerous times. Hence arose the idea of a shield or screen to protect the flame from draught. The first screens were frequently attached to the frame rods, were very irregular in size and form, and were made of various materials, including tin, copper, iron, brass, glass, and horn. They extended sometimes only as high as the flame, sometimes above it, and occasionally nearly to the top. When constructed of opaque material, they of course could not be carried entirely round, and they practically ranged from a mere plate placed behind the flame to a continuous band with an opening on one side. They were fixed sometimes inside and sometimes outside the gauze. Davy lamps with glass shields, Fig. 304, have always been known as "Jack lamps," and in these the glass extended to various heights, and rested sometimes directly on the oil reservoir and sometimes on rings or pegs, the latter arrangement allowing air to pass beneath. These lamps had the advantage of giving more light than the other screened lamps, and were somewhat safer, owing to the continuity of the screen; but they had the disadvantage due to the fragile nature of the enveloping cylinder; and moreover, unless the glass extended well above the point where the smoke-cap overlapped the main gauze, they were but very little safer in rapid currents of air than the unprotected lamp; nevertheless they are still met with in some coal-mines for testing purposes. When the glass shield is extended to the top of the lamp, as in Fig. 305, quite a distinct character is given to the lamp; air-holes have to be provided for the admission of air beneath the glass, and arrangements have to be made for the escape of the products of combustion above. This lamp, which is virtually, although not actually, what is known as a "Davy in case," retained the disadvantage of the risk of fracture of the shield. The next stage of development consisted in enclosing the ordinary Davy lamp in an external case, which sometimes extended to the base of the lamp, as in Fig. 306, and in other instances only enveloped the upper portion. The introduction of the case afforded opportunity for the display of ingenuity, and cases of every available form and of various suitable materials were constructed. The holes in the lower portion of the case are for the admission of air, but it must be remembered that this air has still to pass through the enveloping gauze before it enters the lamp, so that the Davy characteristic is still retained. It is noteworthy that this simple device "converts the Davy lamp from one of the most dangerous into one of the safest of the lamps in common use." A lamp of this form is known as a "Davy in case," or "tin-can Davy." Among the lamps subsequently introduced which resemble the "Davy in case" is Perkins' lamp, in which the gauze cylinder is enclosed in a glass tube, terminating below in a short cylinder of doubled wire gauze, for the admission of air, and having a cover of similar doubled gauze at the top for the products of combustion to pass through.

In Ayton's lamp, Fig. 307, the case takes the form of a cylinder of glass below, and of wire gauze above, the latter being surrounded by a cylinder of sheet metal. The air enters through perforations in the under surface of a hollow ring at the lower part of the case, and then passes, as indicated by the arrows, through holes in a collar protected by wire gauze before traversing the Davy gauze. The Wearmouth lamp, Fig. 308, is similar to the Ayton lamp, except as regards the frame-rods, but the air supply in this instance is obtained through a ring of holes, near the bottom of the case, which are

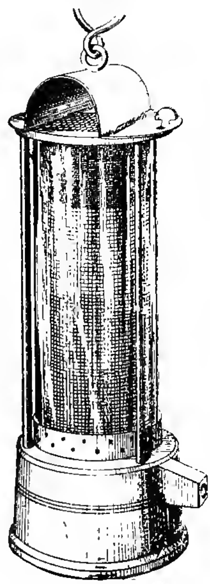
covered by a strip of wire gauze. Fig. 309 represents one of Routledge and Johnson's lamps; in this, the case is of the Clanny lamp type, but the air which enters through holes in the outer sheet-metal cylinder above the glass is prevented from passing directly down to the flame by a second sheet-metal cylinder, which surrounds part of the upper portion of the Davy gauze. The air is therefore directed downwards, but nevertheless has to pass through the Davy gauze in order to reach the flame. The same result was obtained, by a slightly different arrangement, in the Foster lamp. The Pieler lamp, which is a lamp of the Davy type, but not adapted for the purposes of illumination, will be referred to under the head of Gas Indicators. All these lamps on the model of the "Davy

FIG. 304.



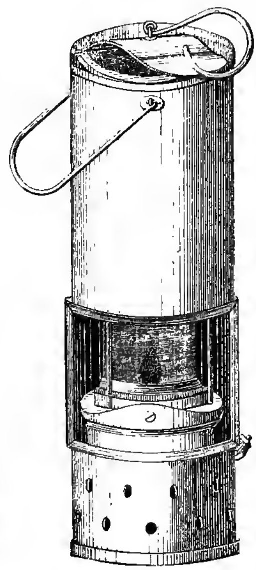
Davy with glass Shield (Jack Lamp).

FIG. 305.



Davy with continuous Glass to top.

FIG. 306.



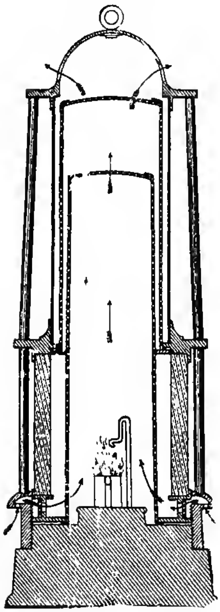
Davy in a Case.

in case," when judiciously designed and carefully constructed, are safe, but they do not give much light.

Proceeding now to the consideration of lamps of the Stephenson type, it should be pointed out that in these the air can only enter above or below the glass cylinder. As already stated, the latter is the way in which it is intended that the air should gain access to the flame, the lower portion of the gauze within the perforated metal ring being left unprotected by the glass with that object. In an undisturbed atmosphere the air follows the desired course, and the products of combustion, escaping above, fill the whole of the upper part of the lamp, as they should do. Under these circumstances, if much combustible gas is present in the atmosphere it ignites only in the lower portion of the lamp, and the heat developed is not strong enough to raise the temperature of the gauze sufficiently high to cause the ignition of the external gas. If, however, there is any deficiency in the air supply from below, due, for instance, to clogging of the apertures or of the gauze, then

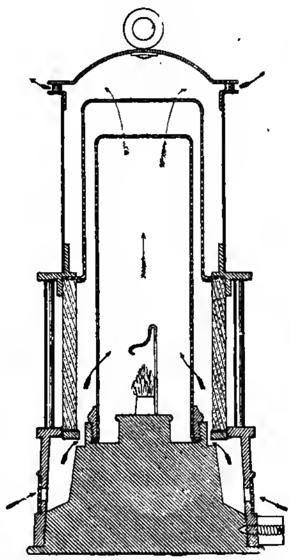
some air is drawn from above and a downward current is created in a part of the cylinder, the products of combustion occupying and passing up another part. The result of this is that the working of the lamp is entirely disorganised, inasmuch as the upper part of the lamp is no longer filled wholly with harmless non-explosive and non-inflammable products of combustion. In a strong current, too, a somewhat similar condition obtains, a stream of air being forced down the windward side, whilst the hot products of combustion have to pass up the leeward. If, therefore, the air is explosive, it may burn at the top of the lamp and heat the gauze to a dangerous degree. If the glass of a Stephenson lamp breaks, the lamp becomes a Davy lamp, but owing to the larger diameter of the cylinder, the former lamp is not then as safe as the latter. An early modification which the Stephenson lamp underwent was introduced to obviate the inconvenience

FIG. 307.



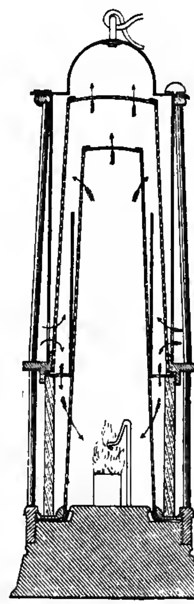
Ayton.

FIG. 308.



Wearmouth.

FIG. 309.



Routledge and Johnson.

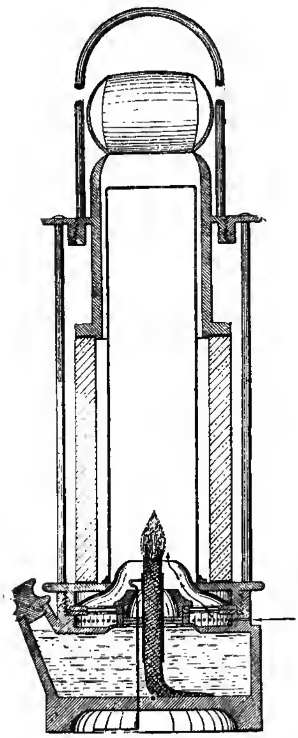
caused by the falling dust choking the air-holes in the vertical band. In place of this band a hollow collar was fitted which enclosed an annular chamber having large apertures opening on to the gauze within the lamp, but communicating with the external air by numerous small holes pierced in the under side of the collar, the arrangement being somewhat similar to the air intake shown in Fig. 307.

The irregularity caused by air currents of high velocity next attracted attention, and in Upton and Roberts' lamp, Fig. 310, we find an arrangement for obviating this danger. The wire gauze cylinder which was attached to the oil reservoir in the usual manner was protected, at the lower end, by a long thick glass cylinder, and as regards the remaining portion by a two-staged cylindrical cap of copper, screwed to the upper ring of the frame and provided with holes at the top for the escape of products of combustion. The glass fitted closely between the cylinder and the cistern, so as to prevent all communication between the interior and exterior.

The air necessary for combustion entered through a range of small openings in the upper part of the cistern into a space protected by a double shield of closely compressed wire gauze, through which it had to pass before it reached the wick. A cone retained these shields in their positions, and also directed the air upon the wick, where it was found in practice to be entirely consumed.

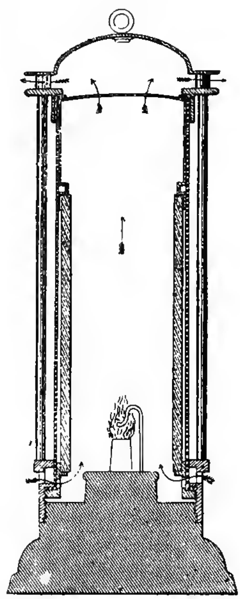
This arrangement was quite safe in any current of combustible gas directed against it, owing to the complete insulation of the interior from the exterior of the lamp. But among other disadvantages, the air supply was deficient, the light was bad, the gauze soon became clogged, and a jerk extinguished the flame. Some of Hann's lamps, as, for instance, that illustrated in Fig. 311,

FIG. 310.



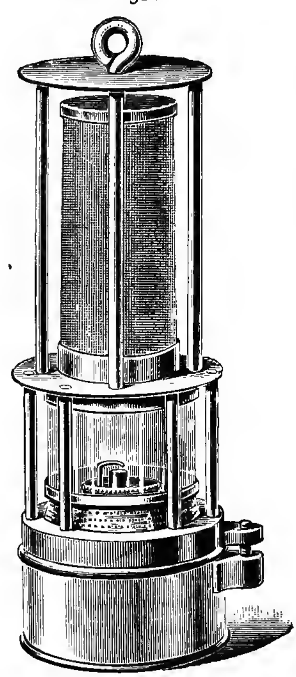
Upton and Roberts.

FIG. 311.



Hann.

FIG. 312.



Boty.

were really Stephenson lamps, but more secure than the original type. In them, the glass cylinder only extended part of the way up the gauze, and was kept in place by a metal tube continued to the top of the gauze. The heated products of combustion could therefore only escape through the top of the gauze and the space between two horizontal flanges at the top of the lamp.

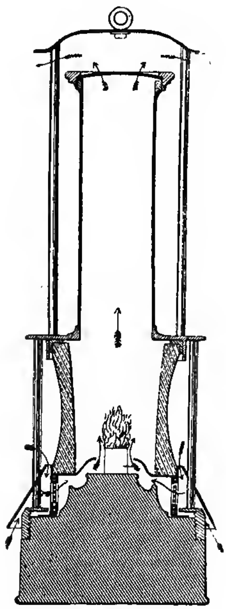
The next steps in the evolution of the Stephenson type of lamp were attempts to improve the light by the abolition of the continuous gauze. The first of these attempts was represented by the Boty lamp, Fig. 312, which in its action resembled the lamp of Upton and Roberts, but the glass cylinder was not protected with wire gauze. In this lamp, which has been many times imitated, a ring of copper, pierced with a number of holes, was fixed to the upper surface of the oil reservoir, and was so arranged that the upper part was

on a level with the base of the flame. A glass cylinder rested upon this ring, and was surmounted by a cylinder of wire gauze. Owing to the rapidity with which the inlet holes become obstructed, this lamp and those constructed on its lines do not, on the whole, so behave as to come within the definition of the Stephenson type of lamp, and at this point it is only necessary to observe that such lamps leave much to be desired as regards both steadiness of flame and safety

4. Lamps of the Eloin Type.

A substantial advance towards improving the lighting power of lamps of the Stephenson type is evident in the Eloin lamp, Fig. 313, in which the wick is surrounded by a glass, shaped like a dice-box, resting upon a short metal cylinder. In this cylinder there are slots, protected internally by gauze, for the admission of air, which is directed on to the wick by a cone. The upper part of the lamp consists of a plain brass tube covered at the top with a gauze diaphragm, which is surmounted by a perforated metal dome, retained in position by the supporting bars. The products of combustion pass up the tube through the gauze and out through the perforated dome. By means of a metal reflector, which slides on the frame bars, the light may be directed upwards to the roof or downwards towards the floor of the mine. While serving the former purpose, as shown in the cut, it also screens the gauze at the inlet from the direct action of the air current, and thus renders the lamp less sensitive under certain conditions. This class of lamp, owing to both ingress of air and egress of products of combustion being facilitated, gives slightly more light than the Upton and Roberts' pattern, but is, however, undesirably sensitive to oblique and vertical currents of air. Moreover, such lamps become highly heated, and the glasses are liable to crack.

FIG. 313.



Eloin.

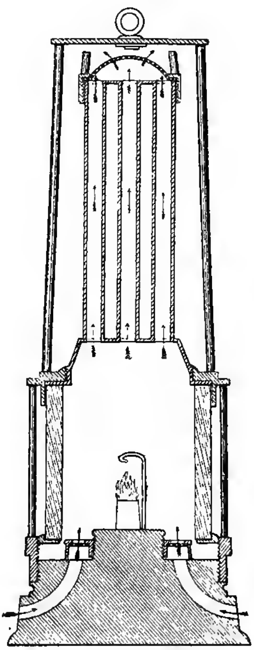
In the Soar lamp, the Eloin chimney was furnished with a perforated metal diaphragm inside, near the top, and a truncated conical gauze cap covering the top, the whole being enclosed in a slightly conical bonnet. The flame was surrounded by two glasses, the annular space between them being closed. All these additions were designed to increase safety and efficiency; the upper arrangements having for their object the diminution of overheating by the provision of more extensive conducting surfaces, and the second glass being introduced to afford the necessary protection in the event of one of the glasses being fractured.

Further attempts towards overcoming the difficulty arising from rapid air currents in this class of lamp are exemplified in the Gardner, Purdy, and Howat lamps. In the first of these, the chimney was made in the form of a cone tapering upwards and terminating in a cylindrical box, with apertures at the top and in the sides, all of which were protected by a closely-fitting gauze cap. The exposure of this gauze rendered the lamp somewhat unsafe. In the Purdy lamp, the chimney was conical and terminated in a diaphragm of perforated copper, over which a gauze cap fitted closely outside the chimney. Outside the whole of the upper part of the lamp, a brass cylinder

was fixed, with perforations at the base to admit currents of air which passed up within this cylinder and cooled the chimney; such currents have been utilised for the same purpose in some other patterns of safety lamps. This lamp, although less unsafe than Gardner's, was not a safe lamp owing to the risk of breakage of the glass. In the Howat lamp, Fig. 314, the chimney consisted of three or more vertical brass tubes, but this did not prove to be an advantageous method of dealing with the high velocity difficulty. Both Bainbridge and Smethurst designed lamps of the Eloin pattern, to which also the Horn lamp and the Timmis lamp belong.

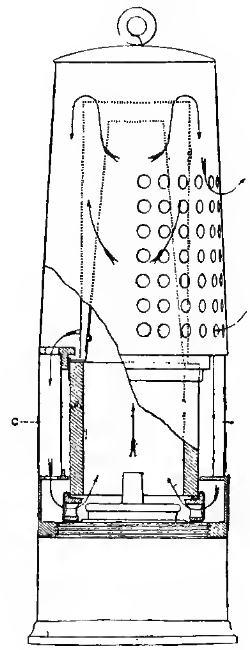
The old form of Fumat lamp was of the Eloin pattern; it had, however, a truncated gauze cone, closed at the top by a metal cap, inside the Eloin chimney, and a fixed metal band to protect the inlet holes. In a new form of his lamp, which is scarcely Eloin in character, Fig. 315, Fumat covers

FIG. 314.



Howat.

FIG. 315.



New Fumat.

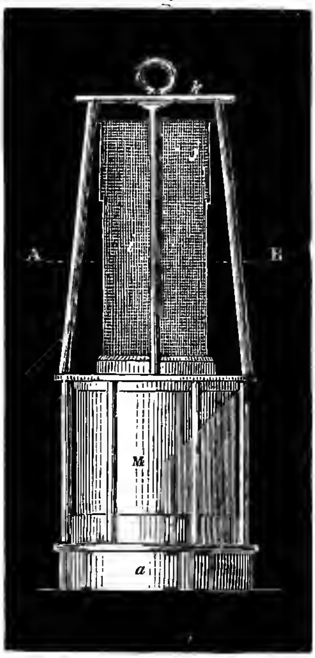
Marsaut gauzes * with a bonnet perforated with several rows of holes on one side. Through the upper ones, the products of combustion escape, whilst through the lower ones the air supply enters, and travelling down a curved box *c*, shielding one quarter of the lamp, passes into an air chamber, and thence, as in the old Fumat, finds its way through a cylindrical band of gauze to the flame. This lamp gives a good light, and burns well in all but upward currents; it is quite safe in strong currents, for although the gas may remain alight for a few seconds inside the lamp the flame does not pass the gauze.

The following lamps of the Eloin class have arrangements for keeping the glass cool, as well as for overcoming the other difficulties; they are all furnished with two glass cylinders, and in most of them the air passing to the flame is caused to descend through the annular space between the

* Marsaut's improvements, see *post*, p. 352.

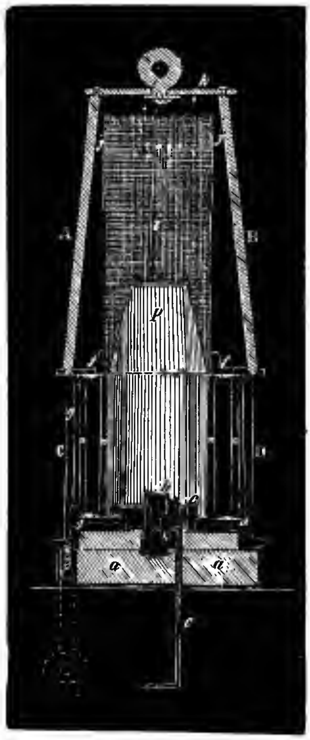
glasses. The chimneys, which vary in form, are continuations of the inner glass cylinders. Earlier forms of this particular kind of lamp were those of Glover and Cail, Figs. 316 and 317, and Hall, Fig. 343 (p. 363). In Glover and Cail's lamp, the oil cistern was screwed into the bottom ring of the frame, the middle ring *f f* being connected with the lower one by the vertical standards *g*. An ordinary wire-gauze chimney *i*, with a movable cover *j*, was attached to the middle ring, and the lamp had the usual ring *k* at the top by which it might be suspended or carried. The air supporting combustion entered at holes made in the middle ring *f f*, and after passing through the meshes of a ring of wire gauze, it descended through the

FIG. 316.



Glover and Cail.

FIG. 317.



Glover and Cail.

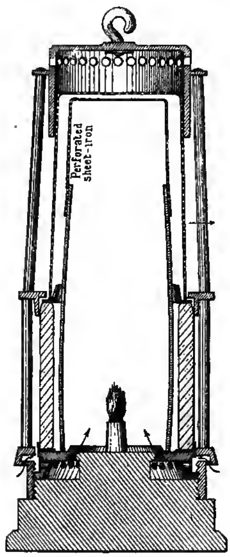
annular passage formed between the two glass cylinders *m* and *n*. These cylinders were supported from below, and rested upon a second ring of wire gauze, which lay upon projecting pieces of the lower ring *d*. The passage of the air from the outside between the glass cylinders effectually accomplished the cooling effect designed by the inventors. A small conical chimney *p*, was placed inside the gauze chamber, a little above the flame, thus promoting a steady draught and preventing any flickering of the light. This lamp indicated the presence of gas with great delicacy, and was self-extinguishing.

The next modification of the Eloin pattern of safety-lamp which deserves notice was invented by T. Y. Hall, in 1852, and will be described later on (p. 364).

More recent forms of this description of lamp are those of Williamson,

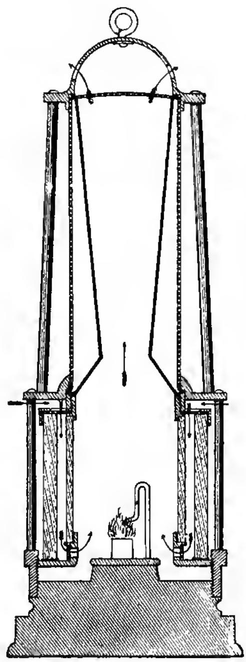
Fig. 318, and Morison, Fig. 319, besides others designed by Pelton, Fig. 320, and Evan Thomas, Fig. 321. The construction of these will be readily understood from the illustrations; but, perhaps, the length and diameter of the internal glass in Williamson's lamp, the cooling current of air in the others, the intake of air being near the top of the Evan Thomas lamp, the formation of a practically undisturbed gaseous cushion around and below the wick in the Morison, and the various forms the chimneys assume, are points worth noting. All lamps of this pattern, however, have some defect; there is either difficulty in lighting, or unsteadiness of flame, or unsatisfactory illuminating power, or complexity in design. The latest and most successful

Fig. 318



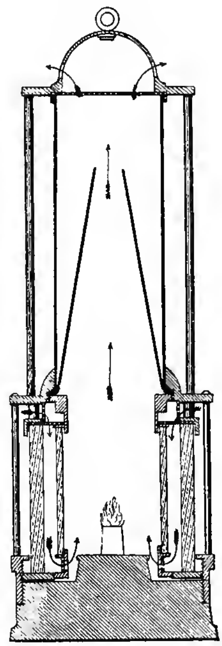
Williamson.

Fig. 319.



Morison.

Fig. 320.



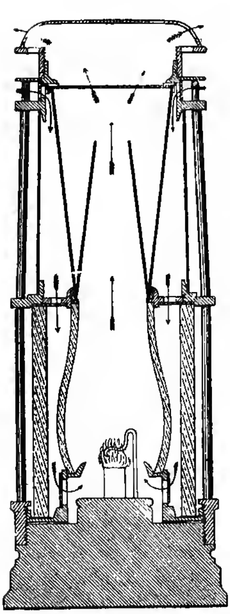
Pelton.

development of this kind of lamp is the Thorneburry, Fig. 322, which will be hereafter described.

An improved form of the Stephenson type and Eloin pattern of lamp, but having distinct and novel features, is the Gray lamp, Fig. 323, in which the frame consists of four tubes down which the air supplied to the flame is drawn into an annular air chamber surrounding a cylindrical strip of gauze below the glass. The early form of chimney was tapering in form and of sheet metal, terminating in a short inverted sheet-metal cone capped by a gauze diaphragm and surrounded by a brass tube covered by a dome provided with large perforations for the escape of the products of combustion. This lamp, however, soon underwent modification, a conical gauze cylinder was introduced in place of the sheet-metal chimney, and the discharge orifice at the top of the chimney was made conical in form. This orifice was also subsequently placed in such a position in relation to the perforations in the cover as to restrict the discharge of the products of combustion, and thus keep the atmosphere

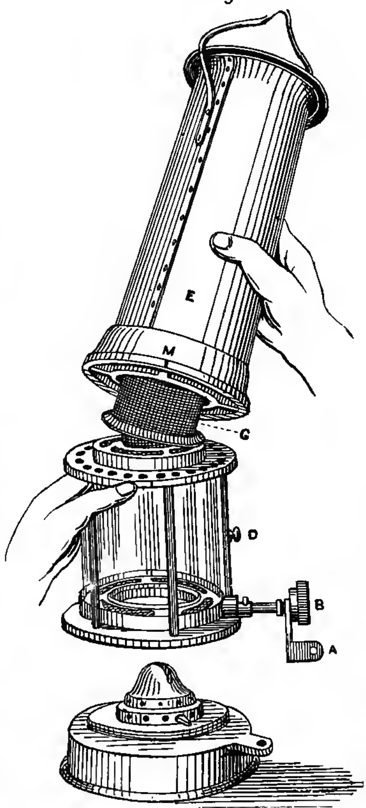
within the lamp vitiated, so as to diminish the risk of internal explosion in accordance with the third condition already specified (p. 336). Next the horizontal diaphragm ring was removed, as it interfered with the upward distribution of light. Then sliding shutters were introduced in the lower part of the tubes, so that when desired for testing or other purposes air might be taken in from below as well as from above; and to facilitate cleaning, the ring supporting the glass, *d*, Fig. 324, was adjusted to the vertical plate of the air inlet chamber. The glass too has been made conical, narrowing upwards, so that light is thrown upwards better, consequently defects

FIG. 321.



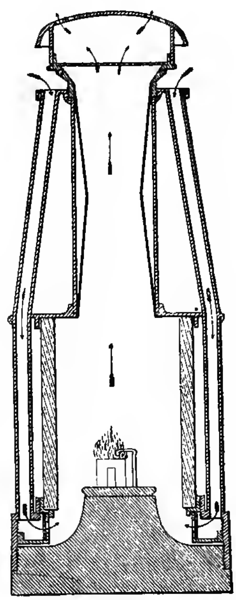
Evan Thomas.

FIG. 322.



Thorneburry.

FIG. 323.



Gray (Old).

in the roof may can be more readily observed without tilting the lamp, and in some cases a crimped cover is added to the lamp to prevent the sudden extinction to which this pattern of lamp is subject. The Gray lamp was one of the four recommended by the Royal Commissioners. The latest form of this lamp, comprising all the improvements enumerated and bearing a name compounded of the names of those to whom the improvements are due, is the Ashworth-Hepplewhite-Gray lamp, Fig. 324.

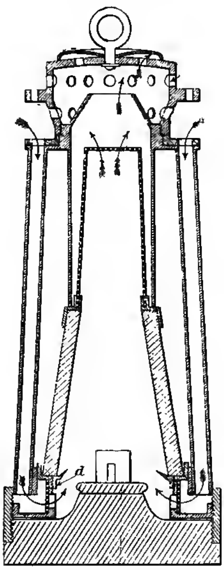
5. Lamps of the Clanny Type.

Passing now to the consideration of those lamps in which the air supply enters above the flame, we find that the earlier pattern of the Clanny lamp

soon proved as untrustworthy in strong currents as the other primitive forms of safety-lamps. Among the improvements which were suggested by Ashworth, Smethurst, and others, was the protection of the gauze by a metal shield or bonnet, perforated for the admission of air, and in some cases so shaped as to direct the air current as shown by the arrows in Fig. 325. This was an improvement on the old form, but left much to be desired on the score of safety.

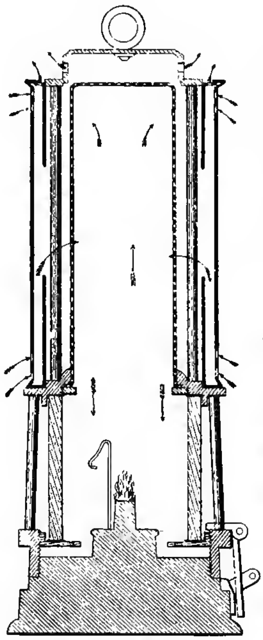
The next step towards increasing the safety of this kind of lamp was the introduction of a second shield of sheet metal, as shown in the illustration of Ashworth's lamp, Fig. 326. This lamp behaves well in strong currents of explosive atmosphere, but becomes very hot, and is moreover extinguished

FIG. 324.



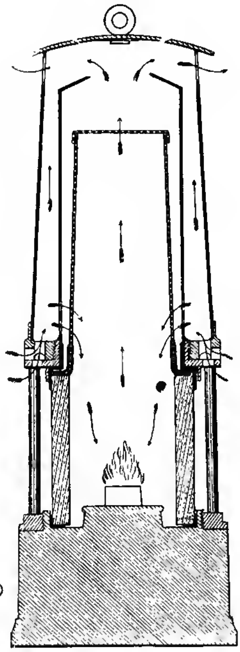
Ashworth-Hepplewhite-Gray.

FIG. 325.



Bonneted Clanny.

FIG. 326.



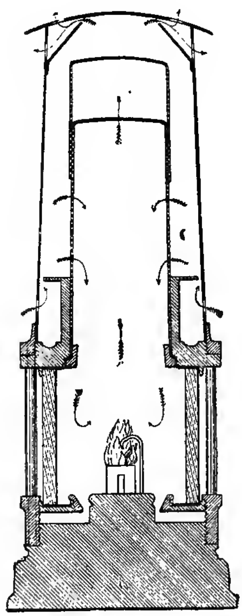
Bonneted Clanny (Ashworth).

at once by even slight inclination—a serious defect, as has been pointed out already.

Evan Thomas also constructed lamps of this class; in one form the bonnet consisted of two metal cylinders, one fitting over the other; there were perforations in both, which ordinarily corresponded, but which could be closed by slightly turning the outer cylinder; the air supply being thus cut off, the light would be extinguished. This arrangement was of doubtful utility, inasmuch as a very slight injury to the bonnet prevented its operating. The internal metal shield in this lamp only reached to the top of the gauze, and was furnished with apertures about half-way up, through which tho air passed into the interior of the lamp. This lamp behaved well in an explosive atmosphere, but gave far too little light to be useful.

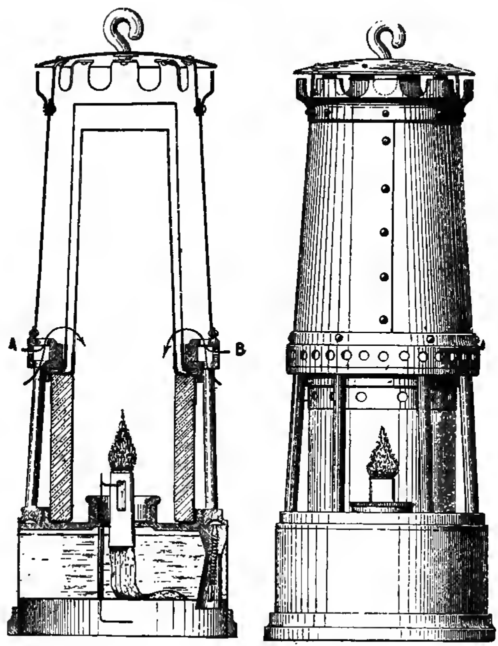
Another form of bonneted Clanny lamp, also due to Evan Thomas, is illustrated in Fig. 327. The oil reservoir, as well as the bars and framework supporting the upper portions, is as usual of brass. The glass rests, on asbestos washers, between upper and lower brass rings; the upper ring extends upwards, and not only supports the gauze, but by being flanged also directs the entering current of air, so that even a sudden rush cannot penetrate directly into the interior of the lamp. The gauze cylinder is closed at the top and is surmounted by a gauze cap. The whole upper portion is enclosed in a bonnet provided with suitable apertures at the lower part for admitting air, and at the upper for the escape of the products of combustion, the egress apertures being, moreover, protected by a conical shield fixed in the bonnet. This arrangement not only moderates the rate of escape of the products of combustion, an advantage already referred to, but also prevents

FIG. 327.



Evan Thomas.

FIG. 328.



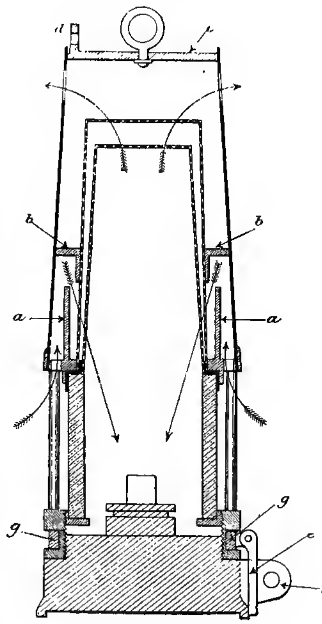
Marsaut.

an inrush of air from above. This lamp when tested burnt brightly and steadily in very rapid currents, and was not extinguished by being inclined until it was nearly horizontal. The Royal Commissioners found that in an explosive atmosphere moving 3200 feet per minute, it showed no signs of being unsafe after an exposure of nearly eight minutes. The gas continued to burn in the gauze cap, and a portion of the gauze quickly became red-hot, but its temperature appeared to be considerably below that required to ignite the gaseous mixture. It was therefore not surprising that this was one of the four lamps specially recommended by the Commissioners.

The next lamp of the Clanny type to be noticed, not in chronological order, but on account of its simplicity of construction, is the Marsaut, Fig. 328, which differs from those hitherto considered, in having inside a bonnet two or three gauze caps fitting closely together at their base on the top of the glass, and gradually separating as they taper upwards. The

bonnet in some has holes at the base for admitting air, A, B and C, Fig. 328, and holes above for egress of products of combustion; in others, which are safer and in more general use, air is only admitted through holes in the under side of the horizontal ring supporting the bonnet, as shown in Fig. 334 (p. 356), an arrangement entirely preventing any danger from an inrush of air from the side. Sometimes, too, a gauze diaphragm is fitted at the top below the egress aperture. With two gauzes this lamp is safe when exposed to currents of 2500 feet per minute velocity; and with three it is quite safe to currents of over 3000 feet per minute velocity. It also gives a comparatively good light, and was another of the four lamps selected by the Royal Commissioners. The Marsaut lamp is largely used at tho present time, owing to its simple construction, its strength, the comparatively good light which it affords, and the trustworthy indications of gas which it furnishes. The last three favourable features are enhanced in Howat's "Deflector" Marsaut lamp, Fig. 329 and Fig. 330, A and B, in which the air entering through the perforated flange beneath the bonnet is directed upwards by a vertical cylinder of brass, *a*, 1¼ inch high, set between the gauze and the bonnet, but touching neither. At about a quarter of an inch above this, the upward progress of the air is arrested by the horizontal part of an angle-ring *b*, which completely spans the space between the gauze and the bonnet, and as the other part of this ring projects in close proximity with the gauze to just above the top of the vertical cylinder, the air is deflected downwards through the gauze on to the flame, as indicated by the arrows, whilst the products of combustion escape through apertures in the bonnet just below the top-plate *c*. In this way, more perfect combustion, better use of the air, immunity from the effects of sudden currents, and improved light-giving power in bad air, are ensured, which, combined with its Marsaut characters, have made this lamp very popular in many districts. In the newer patterns, the deflector takes the form indicated in Fig. 330, C and D; in the former, the bonnet which rests on the flange above the deflecting arrangement is removed, and the deflecting cylinders are shown in section.

FIG. 329.

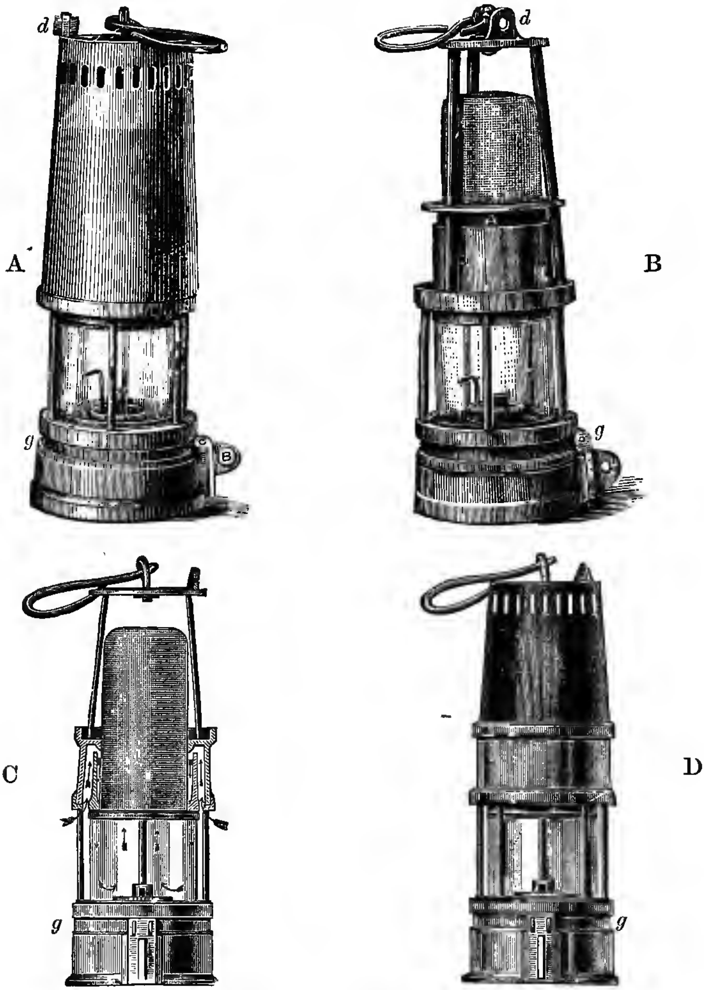


Howat's Deflector.

We are now about to direct attention to another class of lamp of the Clanny type, in which a special channel is provided for the upward passage of the products of combustion. In one make of the Pelton lamp, Fig. 331, for instance, there was an inner corrugated tube, closely surrounded by a plain perforated metal cylinder, which in its turn fitted into the external gauze, the latter being in addition surmounted by a gauze cap and a domed top-plate. The air entered though the gauze, passed through the perforations in the metal cylinder, and descended through the channels of the corrugation to the flame, whilst the products of combustion passed up the central tube. This and also the Thomson lamp, Fig. 332, were, however, not only too complicated in structure for practical purposes, but were also inferior to the Marsaut and Ashworth lamps.

One of the best known lamps of the chimneyed Clanny type, and in fact the first introduced, being but one year the junior of the Clanny itself, is the Mueseler; it was the precursor of the Marsaut lamp, and was invented in Belgium. In fact, Marsaut conceived the idea of his lamp while investigating and improving the Mueseler lamp, and did not base his invention on the ordinary Clanny. The lamp is of the character shown in Fig. 333. The wick is

FIG. 330.

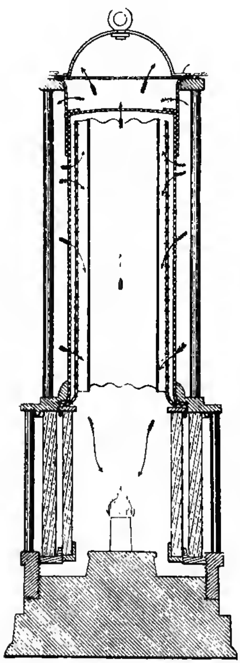


Howat's Deflector.

surrounded by a glass cylinder, surmounted by a gauze chimney, and covered by a top-plate, as in the ordinary forms of Clanny lamps. Unlike the latter, however, the Mueseler lamp is provided with a gauze diaphragm fixed round the edges under the gauze chimney, and stretching across the top of the space encircled by the glass. This gauze supports, in the middle of the lamp, a chimney, consisting of a metal tube, tapering upwards, and expanding at the lower end into a short conical enlargement. When held

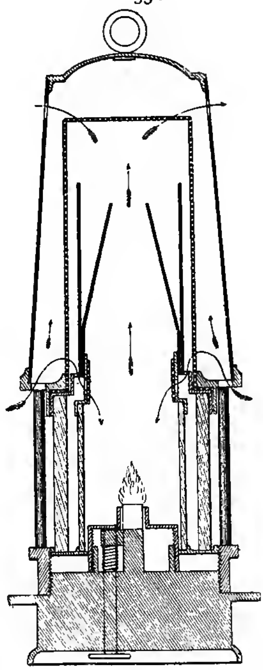
upright, and under ordinary circumstances, the air enters through the lower part of the gauze, and passes downwards through the gauze diaphragm to the flame, whilst the products of combustion ascend through the metal tube and pass out through the upper part of the gauze. Hence, whilst the entering air traverses two gauzes, the escaping gases from combustion have to pass through only one thickness of gauze, and have consequently less friction to overcome. The result is, that under very slight provocation, such as the inclination of the lamp, so that the stream of heated gas rising from the flame strikes upon the gauze diaphragm, or the impinging of a current of air, even of moderate velocity, obliquely on the lamp, the action of the lamp is partially or wholly reversed, and air will pass down the tubular chimney, of

FIG. 331.



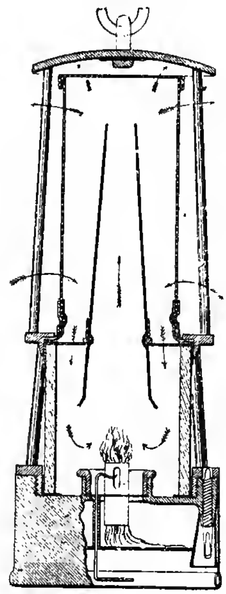
Pelton.

FIG. 332.



Thomson.

FIG. 333



Mueseler.

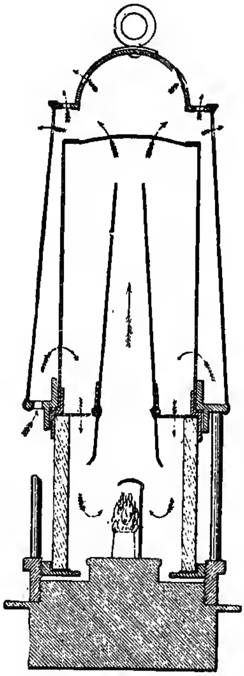
course mingled with products of combustion, for part of these will still ascend, while part will pass through the diaphragm. The result is, that the vitiated air pouring on the flame soon extinguishes the lamp, and this occurs the more rapidly, the nearer the bottom of the chimney is to the flame. If, however, the atmosphere is explosive, and not travelling obliquely, it may ignite below the diaphragm and endanger the glass, but if such a current is rapid and oblique, it may even ignite above the diaphragm, owing to the combustible communication established through the chimney, and thus cause an explosion. To minimise these defects, a Royal Edict was issued in Belgium, fixing the following dimensions and disposition of the chimney in these lamps for use in fiery mines :

	Millimetres.		Inches.
Maximum interior diameter at the top	10	...	0.4
" " " base	30	...	1.2
Interior diameter at the junction of the main cone with the enlargement	25	...	1.0
Height of the enlargement	6	...	0.25
Total height of chimney	117	...	4.6

90 mm. (3.55 inches) to be above the gauze diaphragm, and its base to be 22 mm. (0.85 inch) above the top of the wick-tube.

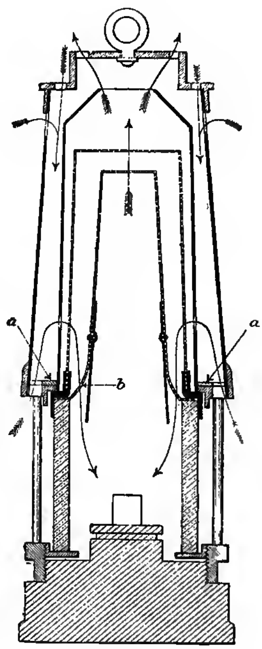
Lamps of this description are in common use in Belgium. In English forms of Mueseler, the chimney is not only higher, which does not invariably affect safety, but the other dimensions of the chimney are altered, sometimes considerably, and the security afforded appears to be diminished thereby.

FIG. 334.



Mueseler (Smethurst).

FIG. 335.



Mueseler (Ashworth).

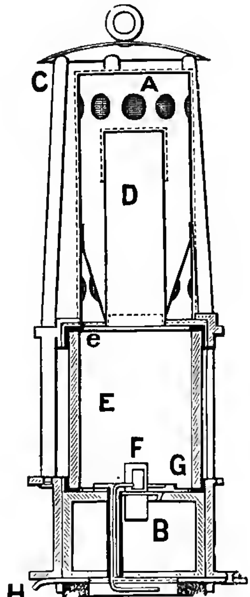
When the gauze cap of a Mueseler lamp is protected by a bonnet fitting well on to the supporting flange (see Fig. 334), which is perforated for the admission of air, ignition of the gas in the top of the lamp becomes practically impossible. Gas may, however, ignite under the gauze diaphragm, but will be speedily extinguished unless the lamp is not well constructed, when it may continue burning and endanger the glass. Even this, however, might be prevented by the introduction of an arrangement for shutting off the air supply. The bonneted Mueseler was therefore the fourth lamp recommended as safe and efficient by the Accidents in Mines Commissioners, but, unlike the other three, it cannot be inclined with impunity. The Morgan lamp is similar to the Mueseler, but all the shields, &c., are doubled. It is very safe, but, like many others, too complicated to be useful.

In more recent forms of Mueseler lamp, made by Ashworth, Fig. 335, a sheet-metal cylindrical shield, having apertures near the base, and a conical

contraction at the top, is fixed between the bonnet of the usual form and the Clanny gauze; whilst instead of the usual diaphragm and metal tube chimney, the diaphragm slopes up all round, and is continued so as to form a closed cylindrical gauze chimney *b*, supporting a short piece of sheet-metal tubing at its lower end. The gauze is thus completely protected, and besides other obvious advantages, by means of a simple shut-off, *a*, necessitating a slight turn of the bonnet, the air can be prevented from entering below the bonnet, and is then drawn down through holes provided near the top of the bonnet, but below the outlet, so that gas can be tested from quite near the roof of the mine workings.

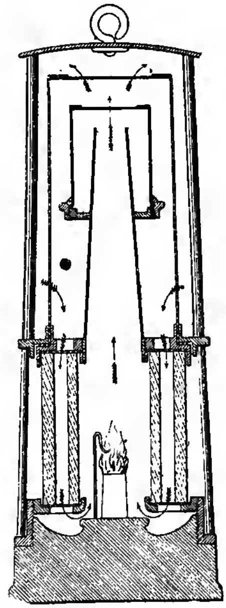
The most recent development of this pattern of lamp is Teale's Piston Safety lamp, Fig. 336. It consists of a shield A covered externally with

FIG. 336.



Teale's Piston Safety-Lamp

FIG. 337.



Mueseler (Bryham).

gauze, and provided with apertures above and below for the egress of burnt gases and inlet of fresh air respectively; a chimney D with gauze above and below to carry off products of combustion, and an inverted cone within the lower part of the shield to screen off the air supply from the vitiated gases above and to direct it down to the flame; the glass E is attached to brass rings at each extremity so as to ensure good joints even with glasses having imperfect edges; then there is the oil-vessel B in which the wick-tube is retained in position by the slide G. The great feature of this lamp is that all these parts, instead of screwing into the frame C, slip into it piston-like, and are prevented from falling out by the pivoted bottom-plate H, which is secured by a lead rivet. I is an india-rubber buffer to prevent the lamp being injured when set down; K is the pricker. The isolation of the products of combustion is a questionable advantage when internal explosion is likely to occur.

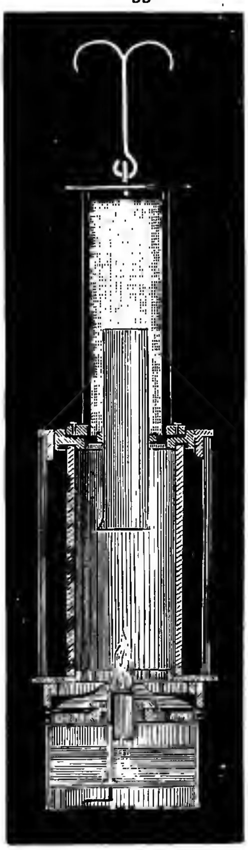
The Garforth lamp was also a Mueseler furnished with a gas-testing

device to be considered later on, whilst the Mackworth lamp was a Mueseler lamp with a glass tube instead of a metal tube for the chimney. The lamp introduced by Stredley also belonged to the Mueseler group. It was a neat-looking lamp, having instead of the gauze diaphragm a ring of unglazed porcelain perforated with holes, and a plate of similar material mounted in a copper shield in place of the gauze cap of the ordinary Mueseler.

6. Lamps of Composite Type.

Bryham's, so called, Mueseler lamp, Fig. 337, had a Clanny case and air-intake, a Stephenson air-feed, an Eloin chimney, and a special gauze cap. This combination introduces us to a class of lamp which is intermediate between the Stephenson and the Clanny types. The Boty lamp, Fig. 312 (p. 345), is a lamp of this type, for although provided with holes below for the admission of air, the provision is inadequate, and as a result much of the air is drawn through the Clanny gauze. In Combe's lamp, Fig. 338, which falls within this category, the cistern, similar to that of Davy, was surrounded by a cylindrical rim, pierced with a series of holes intended to admit the air, and covered with two layers of wire gauze. The air, in passing through, reached a metal dome with a circular opening, which concentrated the whole of the air near the flame. The framework was formed of six rods, connected by two rings. The glass shield rested upon the lower one, with an intermediate piece of cloth or leather. The upper part of the lamp was composed of a trellis protected by six iron rods, and at the bottom a shield of wire gauze supported a copper tube or chimney in its centre, which promoted the ventilation and increased the draught of air through the cistern. The products of combustion escaped through the meshes of the shield and trellis.

Fig. 338.



Combe.

In this arrangement, the air admitted through the perforations and gauze below the flame was always deficient in quantity, and some air was drawn down from above. This second current did not, however, obtain free access to the flame, and the latter was therefore smoky. Moreover, the oil frequently overflowed from the reservoir and choked the underlying gauze, with the result of further obstructing the supply of air.

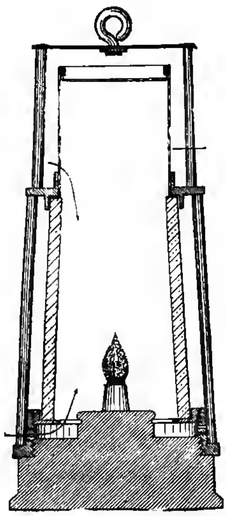
The Gissing lamp was also a Boty lamp with large instead of small holes for admitting air; this alteration did not, however, affect the behaviour of the lamp to any material extent. The Schöne, a German lamp, was a large form of Boty lamp. Bainbridge, Fig. 339, and Glover have also produced lamps of the Boty type.

Combinations of the Clanny and Stephenson air-feed were employed by Fyfe and Hewitson, in their "Improved Clanny," which had immediately above the oil vessel, and below the wick, a series of lateral perforations for supplying air from below, with a floor of single gauze above. The glass cylinder in this lamp was protected by an outer cylinder of talc, without, it

was said, seriously reducing the illuminating power. This shield of talc was found an effectual protection against fracture by the sudden application of cold air or water. The gauze cylinder had a double top, and where the upper part of the glass cylinder met the metal frame, there was a rim of vulcanised caoutchouc, which allowed for the unequal expansion of the glass and metal.

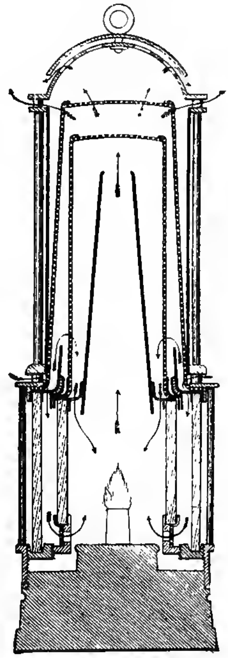
In the Routledge and Johnson lamp, Fig. 340, we had, as will be seen, a Clanny air supply, a small cylindrical directing screen, a Mueseler chimney, very nearly Marsaut gauzes, double glasses with a cooling down-draught of air in the annular space between them, and finally a Stephenson air-feed as a consequence of this downward current. This lamp was really safe when in proper order, but it had the defect that the inner glass, being too near the flame, was liable to become highly heated and thus fractured.

FIG. 339.



Bainbridge.

FIG. 340.



Routledge and Johnson.

When this occurred, the lamp was entirely altered in character, and was no longer safe in strong currents. Another drawback to this lamp was its complicated construction.

Many points of similarity to the last lamp may be traced in the Thorneburry lamp (see Fig. 322, p. 350), which, however, is somewhat less complicated. In the latter, it will be noticed we have double glasses surrounding the flame, a sheet-metal chimney, which, however, is Eloin and not Mueseler, a Clanny gauze, G, surrounding this chimney, an external bonnet, E, with air-openings beneath the lower rim. corresponding with holes in the upper ring of the frame, and a baffle-plate of perforated sheet metal attached inside the lower part of the bonnet to prevent an inrush of air induced by an upward current of high velocity, such as may be encountered in descending a shaft, the whole lamp being surmounted by a top-plate supported slightly above the bonnet. The only framework is that protecting the glass as

well as supporting the upper parts. The glasses are held in position by the upper ring of the frame and a flat skeleton ring of metal, covered with wire gauze, screwing into the lower ring of the frame. Asbestos washers are used between the glass and metal surfaces. The air, therefore, enters through a Clanny-like inlet, passes the baffle-plate through the gauze cylinder, down the annular space between the glasses, and through the ring of gauze into the air chamber. Thence the air travels into the dome surrounding the flame, part going direct to the flame, and part escaping from holes round the dome. Thus the air-supply reaches the flame in a manner similar to that of lamps of the Stephenson type, and is concentrated round the flame by a dome, as in many lamps already mentioned. The products of combustion pass up the long chimney, through the top gauze, and out under the top-plate. This lamp, which is furnished with ingenious locking and wick-adjusting arrangements, burns mineral oil, and has given very good results. It has, however, been objected to as somewhat too bulky, and there appears to be some risk of its working being disorganised by the breaking of the inner glass; moreover, it gets very hot.*

A most interesting and promising combination of principles is exhibited in the recently introduced Williams' Improved Cambrian lamp; in which the air enters underneath the bonnet, as in a bonneted Clanny, then, after passing the gauze, descends hollow standards, extending between the middle and lower frame rings, and reaches the flame as in the Gray system.

7. Unclassified Safety-Lamps.

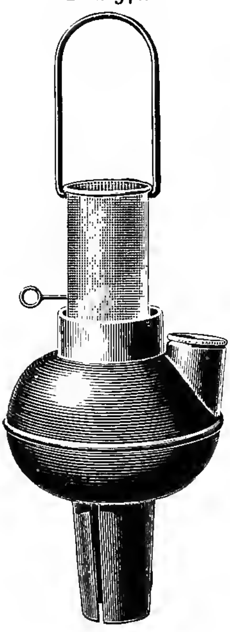
We have now to pass on to the consideration of some lamps of peculiar construction, and although most of them, like some we have already noticed, have never been of any practical value, they are, at any rate, of interest as showing the nature of some of the attempts made to produce safety-lamps for use in fiery mines. Perhaps of this class of lamp the early safety lanterns of Crane should be first mentioned. These were ordinary square lanterns with glazed sides, beneath which were slots, protected by gauze, for the admission of air below the flame, while the products of combustion escaped through a cowl at the top. Crane also introduced a quaint little lamp of the form shown in Fig. 341 (next page). These devices were not safe; they were all too fragile, the lanterns were also too large, and the air inlets and outlets were not sufficiently protected. Moreover, in the case of the little lamp illustrated, the pricking wire passed through the gauze, and made a somewhat large opening, which increased the insecurity. Biram's safety-lamp was like an ordinary hand-lamp; it was constructed of sheet metal, had a silvered parabolic mirror behind the flame, and was closed in front by a door sliding in grooves. The upper part of the door consisted of a flat plate of mica; the lower of a strip of gauze; both being set in a copper frame. The chimney was a metal cylinder with a gauze cap at the top, surmounted by a sheet-metal cover furnished with slots for the escape of the burnt gases.

An advanced form of lantern was devised by J. Evans, Junior. In this lamp, two glasses were provided; the inner one, shaped like an ordinary lamp chimney, was $4\frac{1}{2}$ inches in length, $1\frac{1}{2}$ inch internal diameter at the lower end where it encircles the flame, and $\frac{15}{16}$ inch at the top; the outer glass was $4\frac{1}{2}$ inches in length, and had a uniform internal diameter of 2 inches. These glasses were held in position by brass rings which were supported by stays fixed in lugs projecting from the rims of the rings. The upper part of the lower ring formed a diaphragm round the neck of the oil vessel, and was provided with a raised circular ridge, which retained the glasses in position

* In the latest form of the Thorneburry lamp the burner with metallic dome, shown in the illustration, Fig. 322, p. 350, is replaced by a Barton burner, consisting of a porcelain wick-tube terminating at the upper end in a crescent-shaped spreading lip.

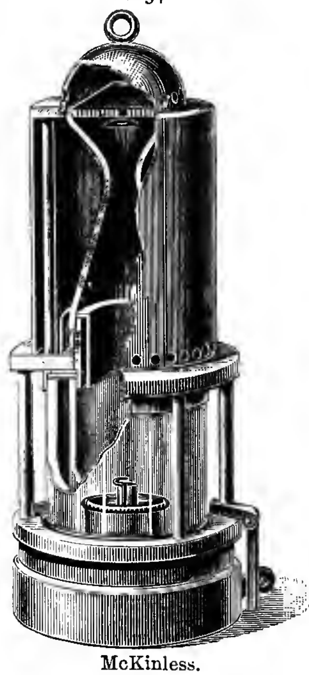
below, whilst at the top a metal diaphragm, furnished with two circular ridges on the under surface, rested on the glasses and held them properly concentric. The upper diaphragm was also provided with a circle of holes over the annular space between the two glasses, and was, moreover, raised in the centre so as to form a small conical chimney. This diaphragm was surmounted by a dome of double copper gauze, the inner gauze being coarser than the outer, and both being mounted on one metal band. An ordinary cowl top screwed into the upper frame-ring, covering and holding fast not only it but also the gauze and the diaphragm. For the admission of air, holes were provided in the cylindrical portion of the lower frame-ring; whilst a raised, threaded and perforated ring, fixed round the neck, on the top of the oil vessel, enclosed an annular space, which was covered with wire gauze at the top. When the oil vessel was screwed home, air passed through the two sets of orifices into

FIG. 341.



Crane.

FIG. 342.



McKinless.

the annular chamber, and thence through the gauze diaphragm into the lamp; part travelling to the flame, and part finding its way between the two glasses. The ordinary flame pricker was used. This lantern, though of good appearance, was obviously useless as a safety-lamp, not only on account of the large area of glass, but also (as to its use in strong currents of air) because of the exposure of the gauzes at the top.

A sort of transition from lantern to lamp is furnished by the Heinzerling lamp, in which an arrangement like an ordinary oil lamp is placed in a cumbersome glass case protected by a frame of metal bars. In the upper and lower parts of the case, gauze boxes filled with glass-wool were fitted; the entering air and escaping products of combustion passing respectively through the lower and upper boxes.

In Haworth's lamp, the air passed through holes, protected by gauze, into a chamber round the top of the oil vessel, and travelled to the flame

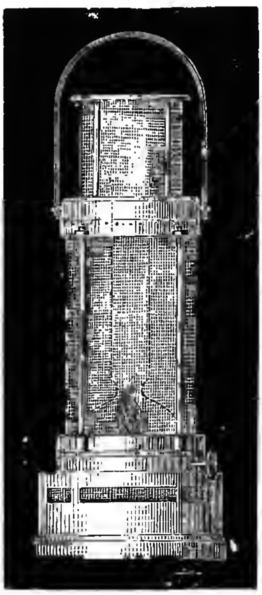
through a perforated diaphragm, protected by gauze, surrounding the wick-tube. The lamp was fitted with two glasses, with a closed annular space between them. The products of combustion escaped through a cylinder of perforated metal into an annular space formed by an outer brass tube, closed at the top by a gauze cap, which in its turn was protected by a covered brass shield, perforated near the top with a ring of holes. The peculiarity about this lamp was that the air chamber round the wick-tube, and the annular space in the top part of the lamp, were connected by two tubes, covered at each end with wire gauze, and passing through the illuminating chamber. Lucas' lamp was a Stephenson lamp, with the addition of a series of radially arranged sheet-metal cells, both at the lower part of the lamp, and above the Stephenson glass. The air, entering through openings protected by wire gauze, traversed the lower series of cells and then passed through a gauze diaphragm to the flame. The products of combustion similarly traversed the upper series of cells, before escaping through wire gauze. In the locking arrangement of this lamp, an iron stud was attached to the back of a hasp hinged on to the lower part of the cage; so that when the lamp was screwed up and the hasp shut down, the stud passed through a hole in the lower ring of the cage and into a hole in the rim of the oil vessel. A metal loop at the end of the hasp then corresponded with a staple attached to the oil vessel, and by means of a padlock the two could be locked together. This lamp was constructed to burn a mixture of mineral and vegetable oils, and hence apparently arose the desire of the inventor to provide an efficient cooling arrangement in the series of metallic cells.

The Humble, a lamp of the Mueseler type, was of finished appearance and somewhat curious construction. The lower part was of not unusual form, but the air inlet was a perforated brass dome, supported by the frame above the glass cylinder surrounding the flame. Immediately above the glass, however, was a metallic plate perforated with small holes, and above this there was a gauze diaphragm, so that the air entering the dome had to pass through both of these on its way to the flame. For the escape of the products of combustion, a tube, extending both below and above the perforated metallic plate, was provided in the centre of the lamp. This tube passed through the diaphragm and dome, as well as through the metallic plate, and terminated at its upper end in a chamber closed below by an imperforate metal plate, the top and sides of the chamber being formed by a cylindrical gauze cap, which was covered with a perforated bee-hive shaped brass dome. The intermediate part of the tube was surrounded by a larger brass tube, to which the lower dome was attached at the lower end, and at the upper end a plate to support the upper dome. The annular space between the two tubes was closed at top and bottom by collars attached to the inner tube. Three gills were provided on the exterior to further facilitate the cooling of the escaping products of combustion. The whole of the upper portions of the lamp were held together by a key passing through slots in the lower part of the chimney-tube within the glass. Across the central aperture of the lower plate supporting the glass, a bridge extended, with a tubular hole exactly in the centre. Through this hole the wick-tube was passed when the oil vessel was screwed up, but on unscrewing the oil vessel when the lamp was alight the wick was drawn down through the hole and the flame was extinguished, so that the lamp could not be opened by removing the oil reservoir without putting out the light.

The McKinless lamp, Fig. 342, is curious in character. In this lamp, in which no gauze is used, the chimney is of brass, and is shaped somewhat like a "ninepin" with about two-thirds of the lower part cut off. Inside the lower end a short flanged tube is fixed, so as to form between it and the wall of the chimney proper an annular

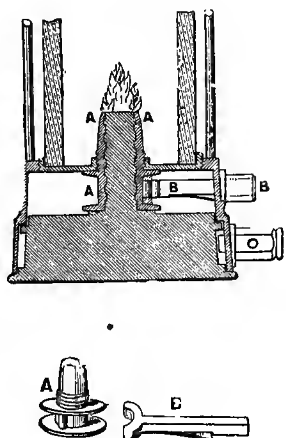
space closed at the top, but open below. The chimney wall at this part is perforated with a great number of small holes, and a short vertical cylindrical brass band encircles the exterior of this portion of the chimney at a short distance from it. This band is fixed on a flat horizontal brass ring which extends round the chimney and covers the space between the glasses. There is thus formed, outside the chimney, a second annular space, closed below and open at the top. The head of the chimney contains a perforated metal plate supporting a conical shield, open above and below, which is covered by a hemispherical dome of brass with holes round the base. A bonnet also fits closely over the whole of the upper part of the lamp, shielding the air inlet (holes being provided round the lower part of the bonnet for the admission of air), but leaving the outlet orifices unprotected. The air entering through the bonnet thus passes into the outer annular space through the perforations in the lower part of the chimney, and thence

FIG. 343.



Hall.

FIG. 344.



Protector.

into the inner annular space, from which it is directed downwards to the flame by the internal tube. This arrangement, although ingenious, has not been found satisfactory, the air supply being insufficient. Moreover, the lamp is expensive and somewhat complicated.

Crossley introduced a lamp intended to be independent of the atmosphere of the mine. This lamp was supplied with compressed air by means of two tubes, furnished with stop-cocks, passing in through each side of the oil vessel and terminating in two small apertures below the wick-tube. To break the force of the air current each aperture was arched over by a small piece of sheet brass. The air passed through a dome of wire gauze, fitting round the wick-tube, before it reached the flame. There were two glass cylinders and air circulated between them.

In the Pendleton lamp, a cylinder of mica surrounded the flame, and was supported on a cylindrical strip of perforated copper, whilst it terminated above at a diaphragm of perforated copper. Round this cylinder was a slightly conical case, composed of five longitudinal strips of copper gauze doubled,

alternating with longitudinal strips of mica set in copper frames. The top of the case terminated in two separated diaphragms of perforated copper below an ordinary bridged lamp-top. When the lamp was properly closed, a spiral spring in the oil receptacle forced a pin into a hole in the case, and locked the two parts together.

T. Y. Hall's lamp, Fig. 343, had two long glasses, and between them a cylinder of silver gauze, the inner glass being of the ordinary lamp chimney form. Air was admitted through small holes round the lower ring of the cage and in a rim attached to the upper part of the oil receptacle. Part of the air thus admitted passed to the flame, round which it was concentrated by the dome of the glass chimney, and part passed up between the glasses, the latter current escaping through some small holes in the intermediate ring of the frame, but when the lower air inlet was obstructed air entered through these holes, which could, if desired, be partially or wholly closed by a ring screwing over them outside. The upper part of the lamp—into which the burnt gases were discharged, subsequently escaping through a gauze disc and a cylindrical gauze cap—consisted of a wire gauze chamber, and was isolated from the lower part by a flat horizontal ring placed above the upper air apertures, and covering the space between the glass chimney and the outside of the lamp. The glasses were pressed against the lower ring by springs fixed above in the intermediate ring of the frame, and the frame itself was hinged on to the oil vessel. An Argand burner could be used with this lamp; Hall also suggested heating the oil by having it in a cistern supported above the flame by hollow standards. The lamp, however, was so complicated in construction as to be useless.

In Dumesnil's lamp, the reservoir was of a rectangular shape, and, with the object of feeding the wick with oil at a constant level, was attached to one side of the lamp, in a vertical position. The wick was flat, and the oil was supplied through a pipe at a level above that of the base of the lamp. Two tubes, slightly inclined towards the side of the wick, supplied the air necessary for combustion. The opening was closed by wire gauze. The glass shield was secured between two metal plates, and was protected from blows by curved iron bars. The lamp was supported by four feet. The chimney of sheet metal was contracted towards the top, where the products of combustion escaped. A double envelope, towards the lower end, projected into the body of the lamp to give steadiness to the flame. When a large quantity of gas was present, a peculiar noise was heard, or, as the inventor expresses it, *Elle crie dans le danger*. It diffused an excellent light, at least equal to that from three Davys, consuming a little more oil, and burning eight to ten hours without requiring attention. The weight and bulk of this instrument prevent it being used as a portable lamp.

This principle as regards oil supply has been adopted by Cambessèdes, who has constructed an Argand lamp which somewhat resembles Dumesnil's lamp, the oil reservoir being attached to one side of the lamp. Although the light is thus obstructed in one direction, yet by means of a reflector it may of course be thrown where it is wanted. This lamp, when burning normally, affords a steady light of $1\frac{1}{4}$ candle.

A lamp of the Clanny type was designed in France, in which the gauze was replaced by a cylinder constructed of superimposed flat rings of iron, maintained at a distance of one millimetre apart. The empty lamp weighed 1225 grams. It was supposed that this arrangement would prove more efficient than the gauze, but this was found not to be the case. In a current of 145 inches per second the arrangement became red-hot, though no explosion took place, but when the velocity of the current was successively increased to 175, 335, and 410 inches per second, explosions occurred respectively in thirty seconds, five seconds, and instantaneously.

8. Automatic Extinction of Safety-Lamps.

Arrangements, more or less automatic in character, have been suggested for preventing a safety-lamp from being at any time converted into an open flame lamp, and many of them are to be seen in the Museum of Practical Geology, in Jermyn Street, London. As an early example of ingenuity in this direction there is a Davy lamp which is provided with an arrangement for extinguishing the flame when the lamp is being opened. On the inner side of the lower ring of the frame, which is made deeper than usual, there is a thin flat horizontal iron ring, having two breaks, opposite one another, filled by two wedge-shaped arms, pivoted at the other end; whilst two unequally armed levers, bent so that the arms make a vertical angle of about 100°, are attached to the top of the oil vessel. The longer arms of the levers are flattened out, and are thin enough to pass into two slits in the opposite sides of the wick-holder; when not in use they are retained in a nearly vertical position by a spring, and the shorter arms are then in a nearly horizontal position on the top of the oil receptacle. The shorter arms terminate in small transverse wedge-shaped blocks. When the frame is screwed on, the wedge-shaped arms in its lower ring pass over the wedge-shaped ends of the levers, and do not disturb their position; when, however, the action is reversed, the wedges in the ring catch the lever wedges, and, in lifting them up, drive the long arms into and down the slits in the wick-holder. As the unscrewing action is continued, the long arms regain their position, but on the next half-turn of the frame the wedges again come together, with the same result as before; the wick is thus battered down, and the flame extinguished before the removal of the oil vessel can be effected.

Another invention for effecting this object is Simon's patent, in which a little spoon-shaped extinguisher is held up by a button, which is wedge-shaped at the lower end, the arrangement being fixed inside the lower part of the frame. In screwing the lamp together, the wedge-shaped portion of the button passes a spring-catch attached to the top of the oil vessel, without its position being disturbed; in unscrewing, however, the wedge is caught by the spring, and this releases the extinguisher, which then falls on the flame and puts it out. Another ingenious device with the same object in view is that attached to Leech's (unbonneted) lamp. A ring, threaded on the outside to screw into an aperture in the centre of the ring supporting the glass round the flame, also screws into the neck of the oil vessel, and has inverted V-shaped notches in its lower rim, corresponding with two similar shaped projections within the neck of the oil receptacle. Thus, in screwing the oil vessel on to the cage, the ring is at the same time caused to screw into the central aperture already referred to. On unscrewing the vessel, however, the projections no longer engage with the notches, and the ring is left in the aperture, with the result that two hemispherical caps of different diameter, which are pivoted on the wick-tube, and are too large to pass through the ring, close over the wick and put out the flame.

In France, also, activity has been displayed in this direction, for years ago Dubrulle suggested a device which has thus been described by Bauerman. The oil vessels are urn-shaped and are made of zinc, and have projecting studs on their outer surface, which fit into three corresponding clutches in a covering plate forming the lower part of the cage. The locking bolt is a bent wire, contained within the oil vessel, with a straight portion at the upper end, which passes through a hole in the top of the lamp, and is received into a hollow boss, lined with brass, in the covering plate. The bolt is maintained in position by a curved copper spring, also within the oil reservoir. The wick, formed of a single thickness of flat cotton plait, is held at the lower end by an iron clip, with a short projecting arm, carrying a

screwed nut or collar, through which passes a vertical screw for raising or lowering it. The iron locking-bolt is also provided with a projecting arm, with a round socket or eye, through which the vertical rod passes loosely, and it is only when the lower edge of the collar on the wick-holder is brought in contact with this arm, that the bolt can be withdrawn; when this is done, however, the flame becomes extinguished by the withdrawal of the wick within its case. In putting the cage on when the lamp is trimmed, the open parts of the clutches are brought over the studs, sufficient pressure being exerted to press back the locking-bolt; the cap is then turned round through a small angle, to make the clutches take hold of the studs, and when they are in position the bolt springs up into its seat, and cannot be withdrawn without screwing down the wick as described. The working of this lamp is somewhat fascinating to witness above-ground, but its complications and other imperfections render it unfit for practical use.

The most simple of these appliances is undoubtedly that adopted in the "Protector" lamp, Fig. 344 (p. 363) in which the wick-tube is long and screws into a long sheath A, the latter, as shown in the figure, being screwed into the central opening of the lower ring supporting the glass. The sheath is held in position by a bolt and clamp B fixed by a spring, and cannot be unscrewed until the oil vessel has been removed, and in doing this the flame is necessarily drawn down into the long sheath and thus extinguished. In preparing this lamp for use, the sheath is screwed on to the wick-tube, the lamp then lighted, and the oil vessel screwed into the lower ring. When the parts are properly adjusted, the bolt is pushed in and the lamp locked.

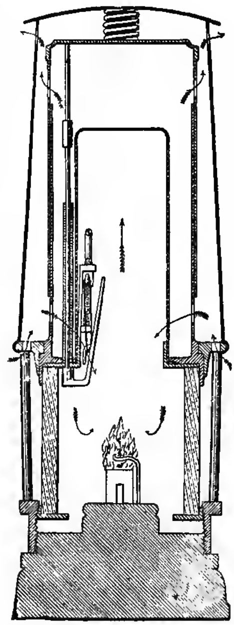
Timmis' lamp was so constructed that the flame was extinguished on the breaking of the glass. This lamp is on the Eloin principle, but the products of combustion pass up a funnel-shaped chimney, which at its smaller, and upper, end is prolonged by a cylinder of gauze, closed at the top by a brass cap. The chimney is surrounded by a brass tube, forming an annular space, closed below. This tube is perforated for about an inch, just below where it surrounds the gauze prolongation of the chimney, and the perforations, as well as the top of the tube, are covered by gauze. This lamp has two tightly-fitting glasses, and through a valve opening inwards compressed air is forced into the space between them. The pressure of the air distends a membrane at the bottom of the annular space, and this forces down a lever which holds on its free end (shaped like a two-pronged fork), a tube sliding freely on the wick-holder. When the pressure of the compressed air is removed, this tube is pushed up by a spring and extinguishes the flame.

Among the best devices proposed for diminishing the risks attending the use of safety-lamps in fiery mines, are those for automatically extinguishing the lamp when it becomes dangerously hot. To effect this, a catch is generally retained by a piece of string or a wire of low melting point, so that when the temperature is sufficiently raised the string burns or the wire melts, and the catch holding in check the extinguishing appliance is released. In the Ballardie lamp, which was one of the Stephenson type but of very different build, the air entered through slots protected by gauze, and passed into a cup-shaped chamber, also covered with gauze. A string retaining a spring was stretched across this chamber, and the spring, when released by the burning of the string, actuated a mechanism for closing the air inlets.

Evan Evans' automatic shut-off, in his self-extinguishing lamp, Fig. 345, which is a bonneted Clanny, consists of two shields between the bonnet and the gauze. The outer shield, which slides over the inner one, is covered with sheet metal at the top, but has a ring of holes near the upper end. The inner shield is fixed on the top of the glass, and has a ring of holes near the base. It is open both above and below. A rod, sliding through a tube

outside the gauze, not only extends below it, but, by means of a flattened turned-up prolongation, is continued upwards a short distance within the gauze, and at this end has a hook attached which can be tied up by string to another hook fixed inside the gauze. The rod, under these circumstances, presses against the top plate of the outer shield and supports the shield in such a position that the holes in both it and the inner shield are uncovered, the lower orifices constituting the air inlet, and the upper ones the burnt gas outlet. When, however, the string burns, a spring fixed on the top of the outer shield, and pressing against the under side of the top of the bonnet, pushes down the outer shield over the inner one, and both series of holes being thus closed the lamp is extinguished.

FIG. 345.



Evan Evans' Lamp with Automatic "Shut off."

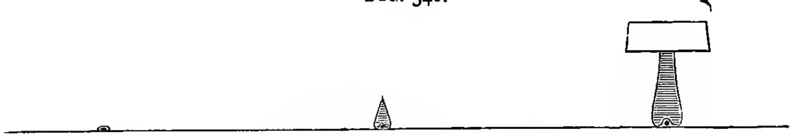
9. Lamps for indicating the Presence of Fire-damp.

Closely allied to the arrangements just described are those devices which notify the existence of high temperatures, and are intended to give warning of danger. Hyde's lamp had a contrivance of this description; the lamp was a large Davy lamp, enclosed in a rectangular metal case with large openings on two opposite sides which could be closed by sliding shutters. The latter were kept open by a hook attached to a rod which passed through the oil cup and was suspended from a fixed support by a piece of string inside the gauze. When gas ignited inside the lamp, the string burnt and let down the shutters, and these released detents from a clockwork bell. An explosion would, however, probably occur before this apparatus came into action. In the Somzee notifier, a metal spiral or bar was so arranged that when it became overheated in consequence of the combustion of marsh-gas inside the gauze, it completed an electric circuit and a bell was rung.

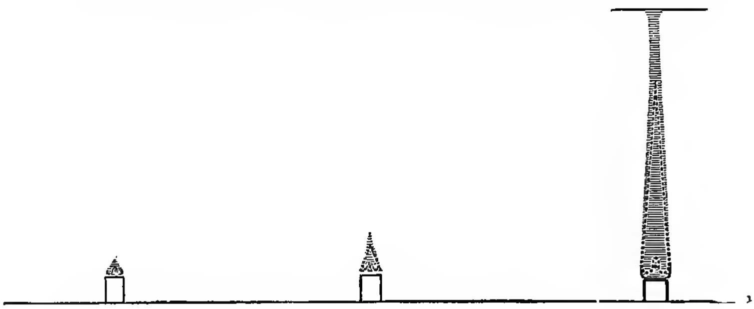
This leads us to the consideration of the various lamp appliances which have been suggested and practically adopted for indicating the presence of fire-damp in a mine. As has already been pointed out, the ordinary gauze-covered flame indicates the presence of marsh-gas in the atmosphere, either by becoming elongated or by the formation of a "cap," Fig. 346. When fire-damp is encountered in a mine, the first indication of its presence is usually an elongation of the ordinary flame. This elongation becomes more pronounced as the quantity of gas in the air increases, and gradually a feebly luminous flame of a blue colour, due to the combustion of the gas, shows itself surrounding the enlarged lamp-flame. This outer flame is generally known as the "cap." With increasing quantities of gas the cap expands, and takes various forms, depending on the construction of the lamp, until the atmosphere becomes inflammable, when the entering gaseous mixture burns at the inlet to the lamp, and the oil flame is in most cases extinguished. In employing the lamp in testing the atmosphere, the wick is drawn down until the flame is greatly reduced in size and is practically non-luminous, so that the feebly luminous cap, when it begins to be formed, may be more distinctly visible. The ordinary lamp does not indicate a proportion lower than 2 to 2.5 per cent. of marsh-gas, but

in spite of this, a small Jack-lamp is still frequently employed for indicating the presence of fire-damp in the working faces of some coal-mines. Fig. 346 is intended to convey some idea of the character of the caps, all the cuts being one-third the actual size. In this connection, it may be mentioned that eminent authorities have asserted, and their assertions have been substantiated, that about 2 per cent. of fire-damp in air which is also heavily charged with coal-dust may constitute a violently explosive atmosphere. This points to the necessity of more delicate testing for fire-damp in order

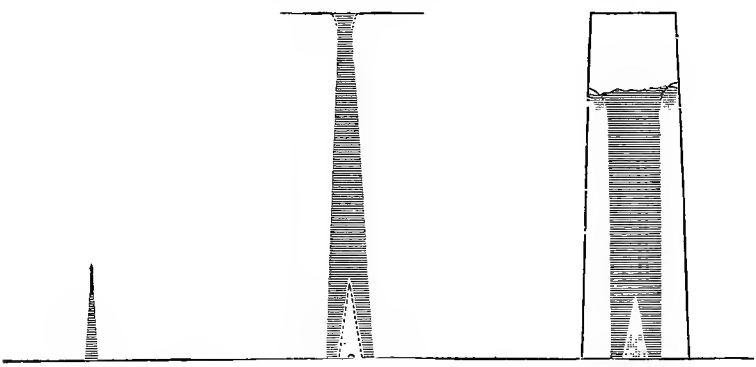
FIG. 346.



Cap" on Mueseler lamp in presence of 2, 3 and 4½ per cent. of gas.



"Cap" on Davy lamp in presence of 2, 3 and 4½ per cent. of gas.



"Cap" on Pieler lamp in presence of ½, 3 and 4½ per cent. of gas.

to ensure safety, but it may be pointed out that a useful fire-damp detector, besides being sensitive, should be simple, portable, and secure.

As regards sensitiveness in the detection of marsh-gas in mines, ordinary lamps may be arranged in the following order:—Gray, Mueseler, Marsaut, Morgan, and lastly Davy and Stephenson. The first of these lamps may almost, in fact, be regarded as a delicate indicator.

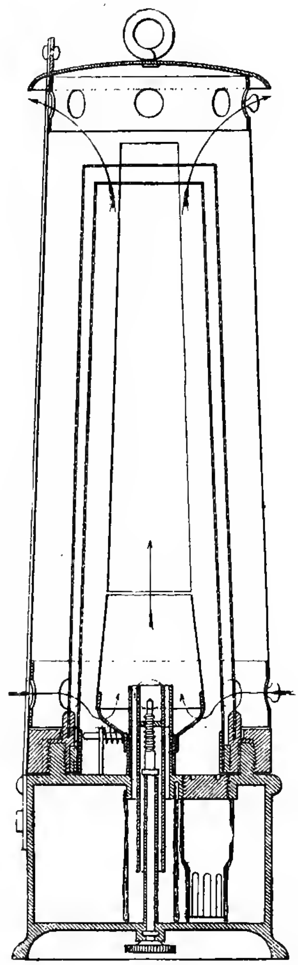
A special advantage of Gray's lamp as an indicator is that, the air supply being taken in from above, the atmosphere immediately beneath the roof of the mine can be conveniently tested. This advantage is, of course, shared

by some other lamps, already alluded to as drawing their supply of air wholly or in part from above, but these lamps have not the other favourable features of the Gray lamp. Many makers of lamps now provide holes near the top of the bonnet, so that on closing those at the base the supply of air is taken wholly from the top. This is the case with Davis Fire-trier's lamp.

One of the simplest detectors is the Pieler lamp, which in its old form consisted of a large Davy lamp, with an Argand wick, constructed to burn alcohol; air was supplied to the inner part of the flame by a vertical tube passing through the alcohol vessel, and protected at each end by gauze. The flame was surrounded and hidden by a short conical screen, and thus the cap was rendered easily visible. This lamp would detect as little as $\frac{1}{4}$ per cent. of marsh-gas in the air of the mine, and with it the following results have been obtained when the flame was 30 mm. high.

In air containing 0.25 per cent. of methane, a cap 30 mm. in height.
In air containing 0.5 per cent. of methane, a cap 65 mm. in height.
In air containing 0.75 per cent. of methane, a cap 75 mm. in height.
In air containing 1.0 per cent. of methane, a cap 90 mm. in height.

FIG. 347.



Pieler.

In this old form, however, the Pieler lamp was unsafe. The latest form of this lamp, Fig. 347, is provided with two gauzes and a bonnet. In the bonnet, there is a narrow longitudinal window, fitted with a sliding shutter, which is opened for purposes of observation. The lamp weighs 1720 grams, and, as regards safety, does not cause an explosion with a current of a velocity of 45 feet per second, even with one gauze, and with the window of the bonnet open. This shows the advantage of a bonnet, even when it has a narrow opening in it. In this lamp, however, an explosion is liable to occur when the supply of combustible gas is cut off; the cause of this phenomenon is the back-rush of inflamed alcohol vapour escaping with violence from the row of holes in the lower part of the bonnet. The Pieler lamp is useless for illuminating purposes, therefore a second lamp has to be carried about with it; in fact, the Pieler lamp should only be used for testing when the ordinary lamp has failed to detect gas.

Chesneau in France has recently introduced a modified Pieler lamp in which the liability to explosion is minimised; to test for gas, he employs Dutch liquid, or methyl alcohol containing cuprous chloride, by this means a very delicate indication is given by cap as well as by change of colour of the flame, but the inconveniences attached to carrying a large non-illuminating apparatus are not eliminated.

For detecting the presence of large proportions of gas in the air filling cavities, fissures or "wickings," where the introduction of a lamp would be impossible or probably dangerous, John Jones suggested withdrawing a sample in a syringe constructed to retain a charge of compressed gas between the piston and the collar through which the piston-rod works, the sample so taken to be subsequently examined, either chemically in a laboratory, or by observing the effect of injecting it into a lamp fitted with a suitable tube for its admission. With the same object in view, Garforth suggested taking a sample in a collapsible india-rubber ball furnished with a metal nozzle. A bonneted Mueseler lamp was used for testing the sample, and for this purpose was fitted with a tube of a small diameter, containing several gauze diaphragms, which passed through the oil vessel close to the wick-tube. The lower end of the testing tube was constructed to fit the nozzle of the india-rubber ball, and was closed with a spring valve. The insertion of the nozzle opened the valve, and on the ball being squeezed the sample of air was forced into the lamp, through the testing tube, the gauze-capped upper end of which forms a burner. This arrangement did not in any way interfere with the use of the lamp for purposes of illumination.

Clowes has recently devised an apparatus for ascertaining the sensitiveness of safety-lamps when used for gas-testing. This consists simply of a gas-tight cubical wooden box or chamber, fitted with a large swinging wooden flap, moved by an external handle, for agitating and mixing the gaseous contents, and furnished with suitable water-sealed openings for the introduction of the lamp to be tested, as well as for the removal of the atmosphere. The chamber is also provided with an inlet tube for gas, an outlet tube, sealed by water, a window through which the behaviour of the lamp under test can be observed, and a hole in its floor through which the pricker may be manipulated. The interior of the chamber and the surface of the flap are painted dead-black.

The results of the experiments made by Clowes with this testing chamber showed that Ashworth-Hepplewhite-Gray lamp, burning benzoline, was an efficient lamp for gas-testing when the flame was reduced in size, by drawing down the wick in the usual way, especially when the "cap" was viewed against a surface obtained by grinding the inner surface of the back of the glass cylinder of the lamp, so as to destroy its reflecting power, or better still against the dead-black background produced by smoking the interior of the lamp glass at the back. Under these circumstances, a distinct flame cap, 7 mm. in height, was seen in air containing only 0.5 per cent. of methane or fire-damp. It was, however, found that the sensitiveness of an alcohol flame was much greater than that of the benzoline flame, and that a hydrogen flame was in this respect preferable to an alcohol flame; moreover, the hydrogen flame possesses the additional advantage over the alcohol flame of being less sensitive to the influence of the presence of products of combustion, and to deficiency of oxygen.

Figs. 348, 349, 350, 351, give the actual measurements made by Clowes of the caps obtained with the colza-petroleum flame, the benzoline flame, and the hydrogen flame. These results exhibit very clearly the superiority of the hydrogen testing-flame, and demonstrate that the delicacy of the test increases with the size of that flame.

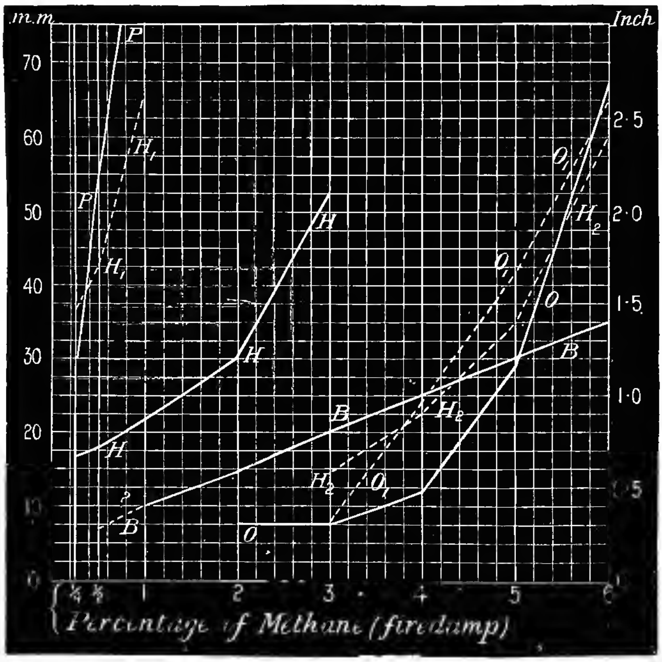
The following general conclusions, drawn from these measurements, and from experience derived from working with the different lamps, are extracted verbatim from a paper by Clowes in the *Proceedings of the Royal Society*, vol. lii. pp. 484–503.

"1. The indications of the Pieler lamp begin at the lowest limit of 0.25 per cent., but quickly become too great to be utilised. The thread-like tip extending above the flame for several inches in pure

air must not be mistaken for a cap, but it is scarcely distinguishable from the cap given by 0.25 per cent. of gas.

"This lamp suffers under the disadvantage that much of the feeble light of the caps is lost by the obstruction of the gauze: the gauze also frequently presents a bright reflecting surface behind the flame, and this renders the observation of the cap impossible. All the other lamps in use are free from the interference due to the gauze, and if their glasses are blackened, as

FIG. 348.



Heights of Methane Flame-caps.

O = Colza-petroleum flat flame (blue).
O_1 = " " " " (luminous tip).
B = Ashworth's benzoline-flame (blue).
H = Hydrogen flame, standard 10 mm.
H_1 = " " 15 mm. in the gas.
H_2 = " " 5 mm. in the gas.

already described, they become well suited for the observation of caps.

"2. The Ashworth benzoline lamp begins its indications doubtfully at 0.5 per cent., the cap thus produced being more distinct, but not greater in height, than the mantle of the flame seen in gas-free air.

But starting with certainty with an indication of 1 per cent., it gives strikingly regular indications up to 6 per cent., and even higher percentages may be read off in a lamp with a long glass.

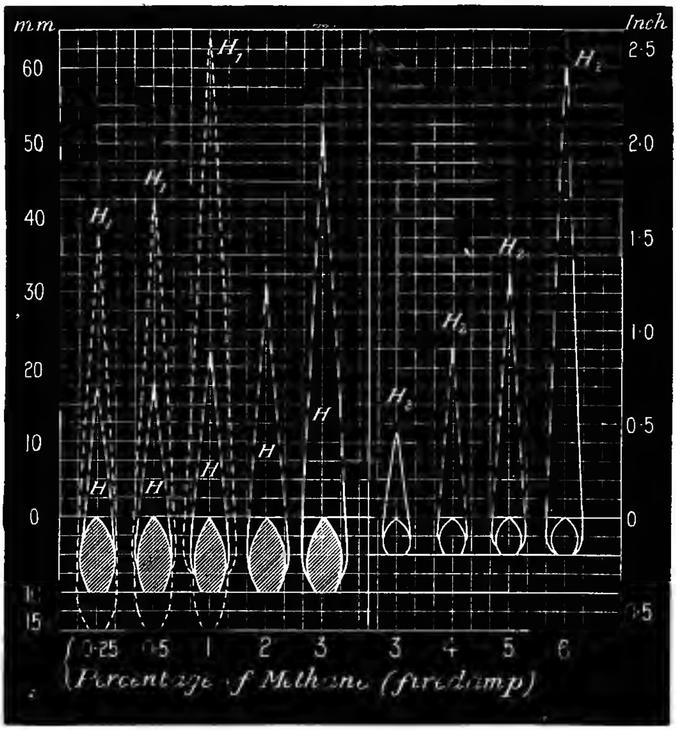
"3. The standard 10-mm. hydrogen flame gives distinct indications from

0.25 to 3 per cent.; the cap then becomes too high for measurement in the lamp; but by reducing the flame to 5 mm., cap-readings may be taken up to 6 per cent. of gas.

The lower indications may similarly be increased by raising the flame to 15 mm.

"4. The oil flame, produced by unmixed colza oil, gives no indications with percentages below 2. With 1 per cent. of gas, the flame from

FIG. 349.



Actual Dimensions of Hydrogen Flames and Caps with Methane.

The shaded flames are of the standard 10 mm. size; their caps are shown at (H).

The dotted flames and caps (H_1) correspond to the flame 15 mm. high in the gas.

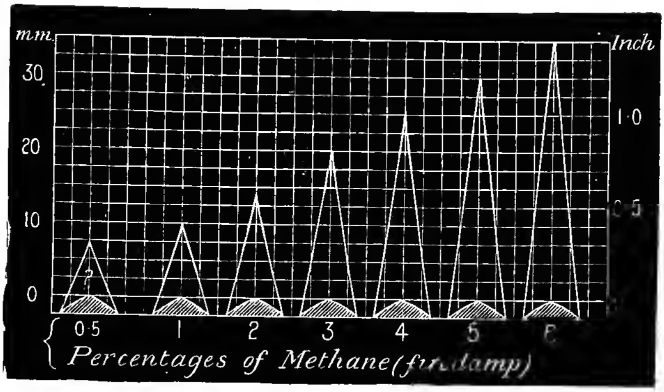
The three figures to the right (H_2) represent 5 mm. flames and their caps; flames set in the gas.

colza mixed with an equal volume of petroleum (water-white) produces an apparent cap, which, though somewhat more intense than the natural mantle seen in gas-free air, is only equal to this mantle in dimensions, and might easily be mistaken for it.

"The oil flame, when it is reduced until it just loses its luminous tip, however, gives distinct indications from 3 to 6 per cent.

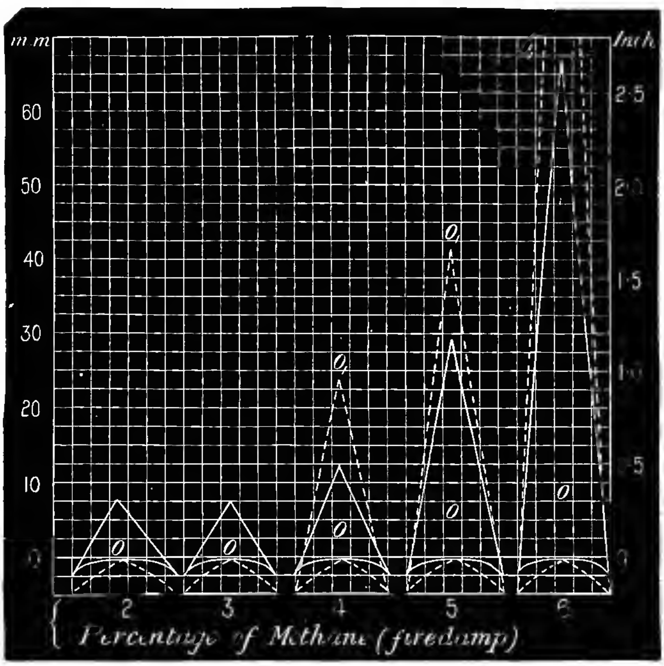
"The largest indications are produced by drawing down the flame *in the presence of the gas*, until a cap of maximum size is obtained.

FIG. 350.



Actual Dimensions of Benzoline Flame and Caps.

FIG. 351.



Actual Dimensions of Oil Flames and Caps.

The continuous lines represent small blue flames and their caps.
The dotted lines represent caps produced when the flame was adjusted so as to give maximum caps.

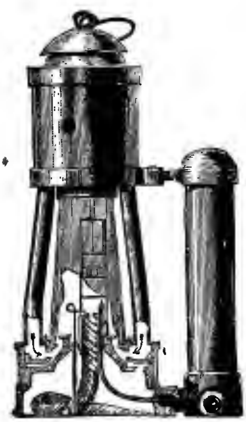
"A carefully regulated oil flame may, therefore, conveniently supplement the hydrogen flame for the indication of gas varying from 3 to 6 per cent., and in the new hydrogen lamp this will be found to be a convenient method to adopt.

"The use of colza alone in the oil-lamp is very inconvenient for gas-testing: the wick quickly chars and hardens on the top, and the flame cannot then be reduced without danger of extinction ; the flame can never be obtained satisfactorily in a non-luminous condition. The admixture with petroleum obviates these difficulties."

Pieler had previously recognised the superiority of a hydrogen flame for use in testing, and suggested that samples of air from the mine should be brought to the surface and tested with a hydrogen flame in a suitable apartment near the pit's mouth ; but Clowes having overcome the difficulties attaching to the employment of hydrogen in a portable safety-lamp, has constructed a gas-testing hydrogen safety-lamp which in its earlier form consisted of an Ashworth-Hepplewhite-Gray lamp, supplied with gas from a small steel cylinder 3 inches in diameter by 8 inches in length, and weighing 4 lbs. A cylinder of this size holds 4 cubic feet of the gas, or enough to supply a flame 10 mm. in height for about 16 hours. The gas passed from the cylinder, which was slung in a leather case by a strap across the shoulder, through a flexible tube, into an opening in the bottom or side of the oil reservoir of the lamp. This opening, which was closed by a self-acting valve when the supply tube was removed, communicated with a copper tube of fine bore passing through the oil vessel and terminating on a level with, and close to, the top of the wick.

Recently Clowes has adopted the arrangement shown in the illustrations, Figs. 352, 353, 354, wherein a small cylinder, holding a sufficient supply of compressed hydrogen to maintain the standard flame for forty minutes, is attached to the side of the lamp, and even forms a convenient handle. The cylinder, whilst securely held in position, is readily detached when exhausted and replaced by a charged one which can be carried in the pocket. The small cylinders are replenished as required from a large cylinder of the usual form containing 10 or 20 cubic feet of gas, about half of which can be used before the pressure becomes too low to give the small cylinders a sufficient change.

FIG. 352.



The lamp while burning oil or benzoline can be used as a source of light, or may, by drawing down the wick so as to produce a non-luminous flame, be employed in gas testing when proportions of gas exceeding 3 per cent. have to be looked for. When, however, the proportion of gas is less than 3 per cent. the hydrogen gas is introduced into the lamp and ignited at the jet, the wick being then drawn down until the oil or mineral spirit flame is extinguished. When the illuminating flame is again required, the wick is pushed up and kindled by the hydrogen flame, and the supply of hydrogen is shut off, and therefore no second lamp is required as is the case with the Pieler lamp.

A very large number of gas indicators unconnected with lamps have been from time to time suggested, but these having already been considered (see Vol. I. "Fuel," pp. 72–75), and being outside the scope of our subject, will not be dealt with here.

Having discovered the presence of a dangerous proportion of marsh-gas

in the air of a mine, the miner should avail himself of the information and withdraw from the dangerous spot until a better condition of atmosphere prevails, but it is important that he should be able to extinguish his lamp

FIG. 353.

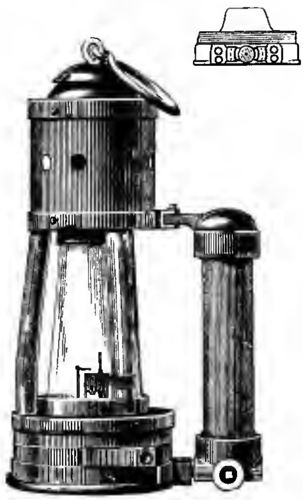
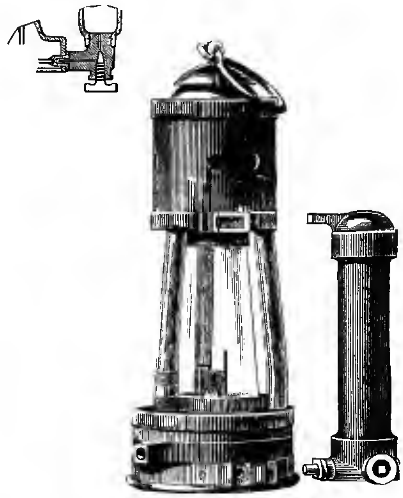
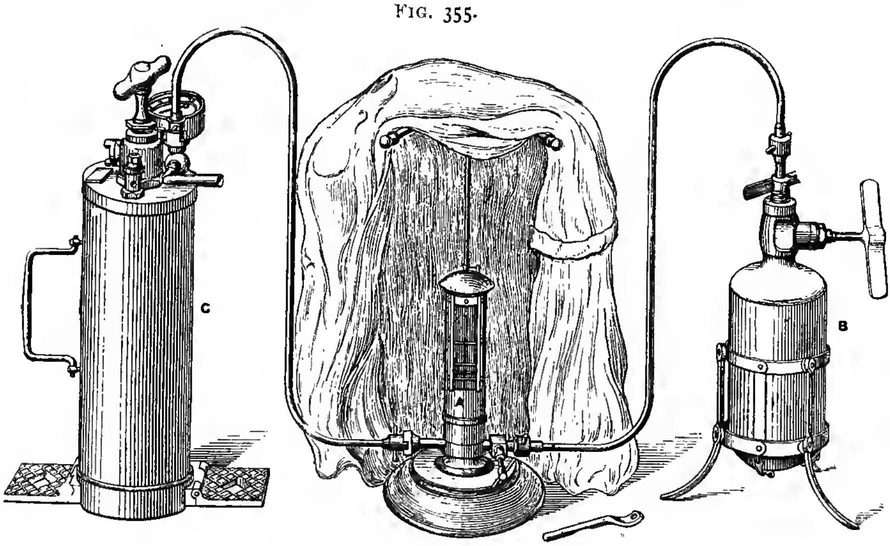


FIG. 354.



immediately, if desired With this object, Evan Thomas proposed the use of a double bonnet, so perforated that by turning one of the bonnets both inlet and outlet could be closed, but it is obvious that a slight indentation would prevent this arrangement from being put into action.

FIG. 355.



It has also been suggested that the same result should be attained by the employment of a ring, perforated at intervals, placed over the inlet or outlet orifices, or both, and admitting of being turned so as to close the orifices. In Davis' Fire-trier's lamp, a horizontal ring of this description is placed

between the bottom of the rim of the bonnet and the perforated flange of the middle ring of the frame. By slightly turning this ring, which is held in position by a spring, the inlet holes are closed, a bar sliding vertically in the frame, and actuated by a spring, fixing it. On drawing down the bar, the ring returns to its former position, and air is again admitted. This device is noticed here as it might be applied for the purpose under consideration, but in the case of the Fire-trier's lamp it is simply used to

FIG. 356.

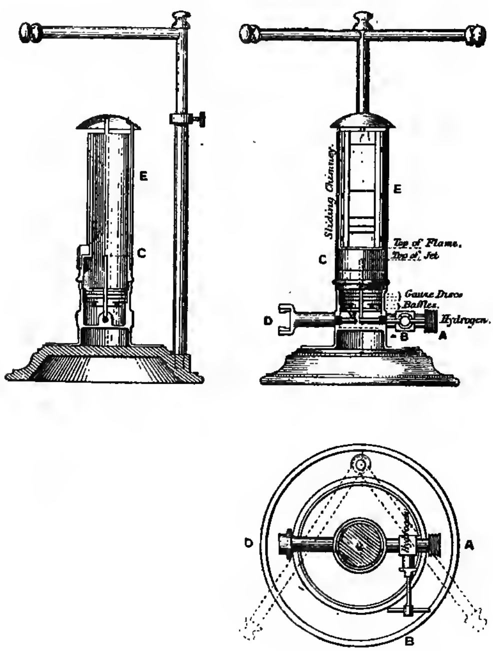
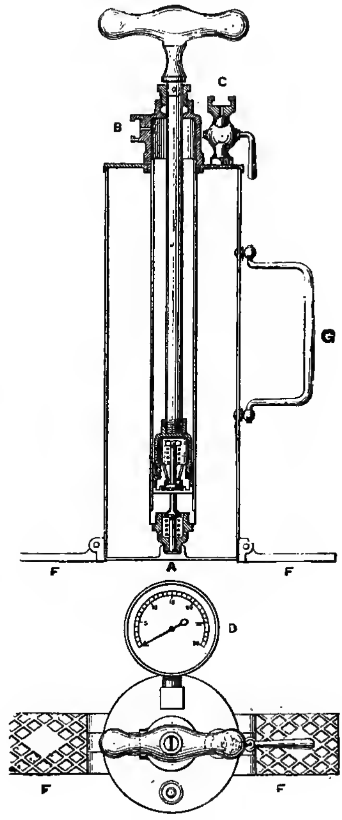


FIG. 35



divert the air supply from the lower to the upper portion of the bonnet as already explained when dealing with indicators.

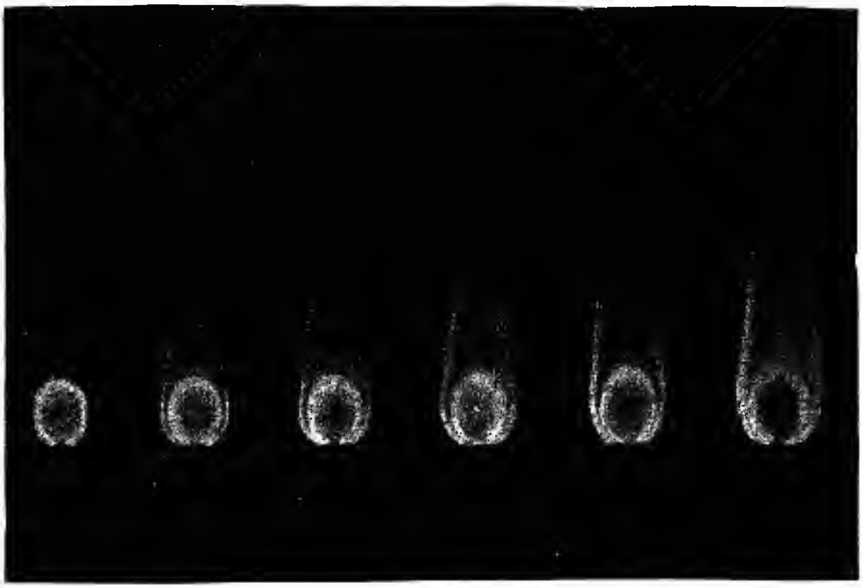
Redwood's Vapour Detection Lamp.—One of the Authors has, in consultation with Professor Clowes and with the assistance of Messrs. W. J. Fraser and Co., recently devised a form of lamp for the application of the hydrogen test-flame to collected samples of air. The apparatus was originally designed for the testing of the atmosphere of tanks and other spaces on board steamships carrying petroleum in bulk, but is obviously suitable for use in the examination of any samples of air suspected to contain inflammable gas or vapour. The arrangement of Redwood's petroleum vapour detection apparatus, which is now largely used, is shown in Fig. 355. The appliances consist of the lamp A, the compressed hydrogen cylinder B, and the collecting vessel C. The lamp is represented in section in Fig. 356. A is the

hydrogen inlet-tube with the regulating valve B, and C is the hydrogen jet. D is the inlet-tube, for the sample of atmosphere to be tested. The bore of this tube is greatly contracted, and immediately above the point at which this tube enters the base of the lamp is an arrangement of baffles, surmounted by three discs of wire-gauze of at least 28 wires per lineal inch, or not less than 784 openings per square inch, the flow of the gaseous mixture to the flame being thus regulated, and the passage of flame into the collecting vessel being prevented. The chimney E fits air-tight at the base, but is capable of vertical movement on an inner tube, the front of which is removed. The chimney is partly of metal and partly of glass, the metallic portion being blackened inside, and on the glass window lines corresponding with various heights of flame-caps may be marked. The top of the hydrogen jet-tube is 10 millimetres (0.4 inch) below the bottom of the window. Attached to the base of the lamp is a telescopic support for a cloth, which envelops the head of the observer and excludes light when the testing apparatus is used in an undarkened room. The construction of the collecting vessel is shown in section in Fig. 357. A is the compression pump, which is furnished with a metallic spring-piston, fitting the pump cylinder without the use of leather or other material, and lubricated with plumbago. Surrounding the pump is an annular space, in which the sample of atmosphere is stored. B is a collar to which may be attached a flexible suction-tube of any desired length. C is a cock, to which is attached a copper tube conveying the sample to the test lamp. The bore of this cock is very much reduced. D is a pressure-gauge, and E a spring valve lifting at 30 lbs. pressure. FF are hinged brackets, on which the feet of the operator are placed while the pump is being worked. G is a handle by which the cylinder can be conveniently carried. The capacity of the pump is 14.84 cubic inches, and of the annular space 169.14 cubic inches, thirty double strokes of the pump being required to charge the vessel to a pressure of 30 lbs. per square inch, when it will contain one-third cubic foot of the atmosphere sampled. It is desirable that the collecting vessel should be fitted with a relief valve, as the apparatus is often used in places in which the dial of the pressure-gauge cannot be easily seen. Having regard to the well-known experiment of the ignition of a piece of tinder placed beneath the piston of an air-compression syringe, it was thought expedient to ascertain the rise in temperature resulting from the compression of the sample, and, with the assistance of Messrs. W. J. Fraser and Co., delicate thermometers were inserted at suitable points, but the increase noted was only from 20° to 30° Fahrenheit. The hydrogen cylinder may be of any desired size, but it has been found that what is known as a 5-feet cylinder is of convenient dimensions. When charged to the usual pressure of 120 atmospheres, it holds enough gas to supply a 10-millimetre flame for ten hours, and is quite portable. The whole apparatus may be packed into two small boxes, and be readily taken on board a vessel.

In the use of the apparatus, the first step is to connect the hydrogen cylinder with the lamp, taking care that the unions are screwed up gas-tight. The sliding chimney of the lamp being raised about half-way, the gas is then cautiously turned on at the cylinder, the regulating valve on the lamp being left open, and a light is applied to the hydrogen-jet. The valve on the hydrogen cylinder is then adjusted so as to give a flame rather more than 10 millimetres (0.4 inch) in length, and the lamp chimney pushed down until there is an opening of only about a quarter of an inch in height at the bottom. This opening is left for the supply of air to the hydrogen flame during the few minutes occupied in the warming of the chimney. As soon as the moisture which at first condenses upon the cold glass has evaporated, the lamp is ready for use, and assuming the collecting vessel to have been

already charged with the sample to be tested, and connected with the lamp, all that remains is for the observer to completely close the sliding chimney of the lamp, adjust the hydrogen flame by means of the regulating valve on the lamp, so that the tip of the flame is only just hidden when the eye of the observer is on a level with the bottom of the window, place his head under a cloth such as is used by photographers, so as to exclude light, and as soon as his eyes have become sufficiently sensitive, turn on the tap of the collecting cylinder, and carefully observe what takes place in the lamp chimney. The tap may at once be turned on fully, as the contraction of the outlet and inlet orifices, already referred to, prevents the rushing out of the contents of the cylinder, and the sample will be gradually delivered into the test lamp during a period of more than two minutes, which is ample time for noting the effect. The rate of delivery is, of course, a gradually

FIG. 358.



a *b* *c* *d* *e* *f*

diminishing one, but this is not found to be attended with any inconvenience, the conditions being tho same in each experiment. In this way a proportion of vapour, considerably below that which is required even for the production of an inflammable mixture, and still lower than that which is needed to give an explosive atmosphere, may be detected by the formation of a flame-cap of greyish-bluo colour, which, though faint, is nevertheless easily seen, especially after a little practice. With an increase in the quantity of vapour, the flame-cap first becomes much better defined, though it is not greatly augmented in size, and then considerable enlargement of the cap occurs, this condition being arrived at before the atmosphere becomes inflammable. One of the Authors and his brother, Mr. T. Horne Redwood, have succeeded in obtaining photographs of flame-caps, which are reproduced in Fig. 358, and convey an accurate impression of what the observer has to look for in employing the hydrogen flame in the quantitative testing of air containing, or suspected to contain, petroleum vapour. Fig. 358 (*a*) represents the standard hydrogen flame in air free from petroleum vapour, and

Fig. 358 (*b*) (*c*) (*d*) (*e*) and (*f*) show the flame-caps produced when the vapour of 0.75, 1.5, 3, 5, and 6 volumes of pentane, respectively, is mixed with 100,000 volumes of air. In each case, a hydrogen flame 10 millimetres (0.4 inch) in height was employed. In taking these photographs, the lens of the camera was placed equidistant between the hydrogen flame and the sensitised plate, so as to give an image of true size. On the assumption that in these experiments the theoretical volume of vapour was obtained from the pentane, the proportions of vapour in the air were for Fig. 358 (*b*), 0.144 per cent.; for (*c*), 0.288 per cent.; for (*d*), 0.576 per cent.; for (*e*) 0.96 per cent.; and for (*f*), 1.15 per cent. Since the investigations of one of the Authors* show that the vapour of 6.65 volumes of pentane in 100,000 volumes of air is the smallest proportion giving an inflammable atmosphere, and that this proportion must be nearly doubled to give an explosive mixture, it follows that the proportion which furnished the flame-cap in Fig. 358 (*b*) was about $\frac{1}{9}$th of that necessary for the formation of a combustible mixture, and about $\frac{1}{18}$th of that which produces an explosive mixture. The test is, therefore, a delicate one; and it is obvious that, if the interior of a tank or other space be ventilated until a sample of the atmosphere gives no flame-cap with this apparatus, an ample margin of safety will be provided.

In taking a sample of the air in a tank, the collecting vessel may be used in the tank, if the proportion of vapour present is known to be small, but even in such cases it is better to employ a short suction-tube, the open end of which can be placed at the lowest point in the tank, where most vapour would probably be found. If, on the other hand, the atmosphere of the tank is suspected to contain so much vapour that there would be danger of its producing insensibility when taken into the lungs, and especially if the compartment is entered through a small manhole, it would obviously be most improper that any one should be sent into the tank, and in that case the sample should be taken by the use of a long suction-tube reaching to the bottom. It is evident that in the case of those tank steamships which have spaces not intended to be filled with oil, but in which oil vapour is liable to accumulate, there would be no great difficulty in having a system of small tubing permanently fitted, which would admit a sample of the atmosphere being at any time drawn off by means of the collecting cylinder in a part of the ship set apart for the purpose, so that a periodical testing of the atmosphere might thus be effected during the voyage or at any other time.

It is perhaps worth pointing out that arrangements have been suggested for rekindling a lamp without opening it, but authorities differ as to the advisability of putting such an instrument into the hands of a miner. Wolf's relighting contrivance consists of a strip of paper, covered with a row of spots of detonating composition, which can be drawn past the upper end of the wick-tube, and at a short distance from it. Each spot when exposed can be ignited by a small hammer, and the flash produced ignites the inflammable gaseous mixture surrounding the wick and then rekindles the flame. This is intended to be applied to lamps burning benzoline. In Elsom's method the wick is relighted by short matches, which are held in a rod passing through the bottom of the lamp, and can be ignited by being brought in contact with and rubbed against a roughened plate attached to the side of the wick-tube.

* Min. Proc. Inst. C.E., vol. cxvi., session 1893-94, part ii., "The Transport of Petroleum in Bulk," by Boverton Redwood.

10. Methods of Locking Lamps.

The importance of preventing the miner from converting his safety-lamp into a naked flame lamp is too obvious to need comment. It is well known that in order to obtain a little more light for his work, the miner will not hesitate to remove the gauze or frame or bonnet of his lamp, although by so doing he incurs the risk of killing himself, and it may be hundreds of his fellow-workmen. It is therefore essential to provide some efficient means of preventing the opening of the lamp. Some of the arrangements adopted for that purpose have been already referred to.

The earliest device for securing the cage to the oil reservoir was an ordinary lock with a special form of key sufficiently long to pass through some portion of the frame, Fig. 300 (p. 337). This was soon superseded by a screw bolt made to work through a boss projecting from the side of the lower ring of the frame into a hole in the upper rim or other part of the oil vessel, Figs. 305, 308. When screwed up, the head of this bolt is countersunk, and being either square or triangular, can only be turned by an instrument like a watch-key. It is, however, not difficult to open such locks with an extemporised key or by obtaining a duplicate key. Sometimes the screw is made to pass through the horizontal surface of the lower ring of the cage into a hole in the top of the oil vessel; in other cases the order has been reversed and the screw bolt passes upwards through the oil vessel into the cage ring, Figs. 317, 328, 333; whilst examples are not wanting wherein the locking bolt extends from the intermediate frame ring into the oil receptacle. These latter arrangements possess the advantage that they do not necessitate any projection from the side of the lamp. Hasps with staples and padlocks have also been employed for this purpose, Figs. 304, 325, 329, 342; as also have screws with caps and various complicated devices, which proved more or less inconvenient and imperfect, and have naturally fallen into disuse.

The best system now in use consists in connecting the lamp and case by a rivetted lead plug, which is stamped with a special mark or letter, so that any tampering with it may be detected. For this purpose, projecting metal lugs are provided on the sides of the cage and oil vessel in such positions and so perforated that the holes in them correspond when the lamp is screwed up, Fig. 312; the lead plug is then passed through the holes and rivetted firmly by the use of a pair of pincers, carrying in one of its jaws a die with the selected device. In lamps having a movable bonnet, a second locking arrangement is frequently provided for attaching the bonnet to the frame, Figs. 330, 331. But contrivances also exist for locking both the bonnet to the cage and the cage to the oil vessel at one operation. In Ryder's patented locking apparatus, a rod slides up and down in holes in the intermediate and lower ring of the frame, and is long enough to extend beyond both these rings. When the bonnet is screwed or otherwise fixed in position, the rod is pushed up into a socket provided to receive it, and the frame is then screwed on to the oil vessel. When these have been properly adjusted, the rod drops into a small hole in the top of the oil vessel, and at the same time extends upwards through the frame into the lower part of the bonnet. All the parts are thus held together and one lead plug suffices to lock them. By a very neat arrangement, Ryder has dispensed with the projecting parts. The rod slides through a brass boss fixed underneath the intermediate ring of the frame, and when all the parts are properly adjusted it extends both into the oil-can and into the bonnet; horizontal holes in the boss and in the rod respectively then correspond and a lead plug inserted in them is rivetted and marked in the manner already described. This forms an exceedingly neat and practical lock. In the Thorneburry lamp, Fig. 322, the sliding

rod D is actuated by the hasp A, which when brought into correspondence with the lug B can be secured by a lead rivet, thus locking together the different parts of the lamp. A device to expedite the operation of rivetting has been introduced by Morgan. The projecting parts to receive the seal are made longer than usual, and the vertical hole which pierces the lower one does not completely extend through the upper one. The lower projection is, moreover, furnished with a spring catch which allows the cylindrical lead plug used to be pushed up, but the plug has, near the lower end, a groove into which the catch fits. The plug when driven home is thus held by the catch and cannot be withdrawn, neither can it be pushed out from below, the end of the upper projection being closed. This is an expeditious system of locking, but one which affords far less security against tampering with than those which involve the use of pincers and die.

It should be pointed out that the various systems of locking which depend on the introduction of a lead rivet into holes or sockets set on or in the cage and oil vessel, so that they correspond when the two parts of the lamp are properly screwed together, possess a serious defect. The correspondence being of course provided for when the lamp is new, it follows that when the screw threads become somewhat worn by constant use, the tendency is for the one hole to pass slightly beyond the other when the cage is tightly screwed on to the top of the oil vessel. As it would then be impossible to insert the lead plug, it may be said that, when worn, the lamp cannot by this method be both securely closed and locked, and it follows that lamps may thus be sent into the mines imperfectly screwed together and possibly in a dangerous condition. To obviate this, the lower lug has in some cases been made to extend some distance round the oil vessel, and has been perforated with a row of holes, so that there is always approximate correspondence between the hole in the upper lug and one of the perforations in the lower plate when the lamp is properly closed. But a better arrangement than this has been introduced by Howat, Figs. 329 and 330, one of the lugs, or it may be a hasp, being attached to a countersunk moveable collar, so that whatever the condition of the screw, the locking parts can always be brought into correspondence.

In addition to these simple devices, locks for lamps have been suggested and used which require a strong magnet or an air-pump to undo them; others again, Cuvélier's for instance, are fastened by a pin kept in position by means of a manometric tube charged with liquid under pressure which can only be released by means of a special machine, and in one contrivance the removal of the lock and pin necessitates the unsoldering of a protecting plate.

11. Various Parts of the Safety-Lamp.

It becomes necessary now to make a few general remarks in reference to the various parts of safety-lamps.

The Frame.—This is needed to unite, support, and keep in position some of the component portions of the lamp, and it must be capable of withstanding the rough usage, and wear and tear inseparable from coal-mining; at the same time it is essential that the frame should not add greatly to the weight of the lamp. Frames should therefore combine rigidity and strength with lightness. In lamps of simple construction, such as the Davy lamps, the frames consist merely of three or more stout, straight iron or brass wires, which are rivetted, in a vertical or inclined position, to a substantial metal ring below, and to a smaller metal ring or plate above, the lower ring, as in most other safety-lamps, being

threaded to screw on to the oil vessel, Figs. 297, 300, 304, 305. Stephenson's lamps were furnished with similar frames, the only modifications introduced being those which were necessary to retain the glass as well as the gauze in position, and to furnish the air inlets and air chamber. Even, however, in these simple lamps an auxiliary ring is sometimes added; this screws within the lower ring of the frame and helps to support the glass, forms part of the air chamber, or discharges some other useful function, Figs. 301, 310, 311. The top of the frame may be a metal ring supporting a flat, domed, corrugated, or arched metal plate, to which is attached the ring or hook for carrying the lamp. The plate protects the miner's hand from being scorched by the heated products of combustion; it also protects the interior of the lamp from falling matter, liquid and solid; these remarks apply to to nearly all other safety-lamps. The next description of frame to be considered is that which was called into existence by the requirements of the Clanny lamp. In this pattern, the frame is constructed in two stages, with an intermediate or middle ring, which may or may not be threaded; this middle ring is connected with the upper plate or ring by the usual number of stout wires, which are frequently inclined together at the top, the upper part of the frame thus having a taper form given to it. The middle ring is similarly attached to the lower ring by five, six, or eight smaller wires, which are usually vertical, Figs. 303, 312, 313, 314, 316, &c. These wires serve to protect the glass, and their smaller size is advantageous as they throw less shadow. In a few lamps, the same rods protect the glass and also support the upper parts, Figs. 307, 309, 321.

In some lamps, Evan Thomas', Fig. 327, the Marsaut, Fig. 328, and the Thorneburry, Fig. 322, for example, the upper part of the frame is dispensed with, the character of the materials, or the form of construction of the lamp, affording sufficient rigidity and strength. In some cases, the frames take exceptional forms: for instance, in the Gray pattern of safety-lamp the air supply tubes form the supporting stays of the frame, Figs. 323, 324. The auxiliary ring within the lower ring of the frame, already referred to, is either perforated or provided with notches, so that by the insertion of a suitable key or implement, it can be screwed in or out, and release or adjust the glasses or any other part it may be supporting.

The Oil Vessel.—The oil vessel, reservoir, or can of the safety-lamp is usually cylindrical in form, but has, as we have shown, been made in other forms, and is constructed with a neck in which the wick-tube or carrier is held by a threaded ring. In this country, the oil vessel is usually made of brass, whilst on the Continent the material preferred is iron, but tin and zinc have also been employed. Recently, oil reservoirs have been constructed with a brass body and tin top, with the object of minimising the conduction of heat to the oil, for it is found that the vegetable oil commonly employed has a tendency to become "gummy" when continuously exposed to a high temperature, and that in such a condition it does not freely ascend the wick. The oil-can usually has a small tube passing through it from the base to the top, in which a wire, serving for trimming and adjusting the wick, works tightly. The top of the oil vessel is, as will be seen from the various illustrations, modified in many cases to meet the special requirements of the lamp; sometimes, too, the reservoirs are traversed by tubes for the admission of air, as in the cases of the Pieler, Howat, and other lamps, Figs. 347, 314. This arrangement is, however, not a good one, as the inlet holes are liable to become choked with dirt when the lamp is placed on the ground in the mine. In some cases, of which instances have been given, the oil vessel has been made to contain self-extinguishing or other mechanisms.

The Wick.—The wicks used in safety-lamps are generally of plaited cotton; asbestos has, however, been partially substituted for cotton in the composite wicks of the Protector lamps; they are sometimes round, sometimes flat, and in a few exceptional cases are tubular (Argand), the last form necessitating a central air supply. The wick-tube is flat or round, and is carried some distance both above and below the plate supporting it in the lamp-neck. A short distance above this plate, there is a slot in the tube into which the curved end of the pricker can be inserted with a view of pushing up or drawing down the wick as desired; this slot should not be unnecessarily large, for when the lamp becomes heated the wick may be ignited here if any considerable area of it is exposed. With flat wicks, it is found desirable to employ a wick somewhat too wide and too thin for the wick-tube, for the wick is thus caused to assume a wavy form, which is favourable to the flow of oil to the flame. The same result is obtained if the wick-tube is guttered along one side; the latter suggestion is due to A. H. Stokes, and the former to Ashworth. Some special forms of wick-tubes have already been noticed, but one other, that adopted in the Rotherham lamp, may here be described. The burner consisted of a glass tube $\frac{1}{4}$ inch in diameter, fixed concentrically in a cylindrical porcelain tube $\frac{7}{8}$ inch in diameter, the annular space between the two being filled with a porous cementing material. At the top, the porcelain tube was somewhat flattened so as to form a long narrow orifice $\frac{3}{4}$ inch by about $\frac{1}{8}$ inch, the ends of this orifice being spread out and turned up so as to give it somewhat of a V-shape. A twisted cotton wick passed through the glass tube, and the oil travelling from it into the porous composition burnt at the narrow orifice of the porcelain tube.

The simple form of the pricker does not call for further notice, but it should be remembered that its function as regards raising and lowering the wick has been effected by different arrangements in the Hall, Thomson, Thorneburry, and other lamps.

The Royal Commissioners on Accidents in Mines reported that many so called improvements on the solid cylindrical wick employed in the Davy lamp and other early forms of safety-lamps resulted in the production of flaring and smoky flames. They found that the best results were obtained with the wick used in the Marsaut lamp. This was described as a loosely plaited flat cotton wick, 0.5 inch in width, and it was fitted into a wick-tube 0.4 inch in width. With this arrangement a good oil was found to burn satisfactorily for the maximum duration of a shift, if the wick was in the first instance adjusted so as to produce a flame not exceeding an inch in height, and the pricker was used occasionally. Whilst, as has been already pointed out, it is advantageous to employ a wick somewhat wider than the wick-tube, the wick must not be of such size that it is tightly compressed into the tube or carrier. Plaited wicks should be made of good long-staple cotton loosely woven. All cotton wicks absorb moisture, and as this diminishes their capacity to raise the oil by capillary attraction, it follows that the wicks should be dried in front of the fire or in an oven immediately before use. The wick should be only slightly larger than the depth of the oil reservoir, and should be frequently renewed, as the capillary channels are liable to become obstructed.

The Glasses.—The glasses used for safety-lamps are usually cylindrical in form, and about $2\frac{3}{4}$ inches in height by $1\frac{3}{4}$ inch internal diameter, the material being from $\frac{1}{4}$ to $\frac{1}{2}$ inch in thickness. In some cases, the dimensions of the glasses vary somewhat from those given, and in exceptional cases, as for instance in that of the Bainbridge lamp, Fig. 339, glass cylinders 4 inches in height are used, but such glasses are not only more liable to be fractured, but possess the great disadvantage of offering additional resistance to and

adding to the violence of internal explosions. Special patterns of glasses have been described, for example, in connection with the Eloin and Ashworth-Hepplewhite-Gray lamps, Figs. 313 and 324. and sufficiently indicate that glasses of various forms are employed. In the Ballardie lamp, in the lamp of Routledge and Johnson, in the Eloin lamp, and in other lamps, glasses with parabolic surfaces have been used. Glasses of lenticular and other forms have also been introduced, but none of these modifications has survived an extended practical test. Inverted paraboloid glasses constituted the special feature of Colonel Shakespear's lamp, but were found more liable than the ordinary glasses to fall to pieces when cracked. The advantage of conical glasses has been already indicated. Double glass cylinders have, as we have seen, been introduced in many lamps, the inner glass sometimes taking the form of the ordinary lamp chimney, and at other times being simply a plain cylinder. In either case, the inner glass is usually thinner than the outer. In some lamps, the space between the glasses is closed, in others it is open for the circulation of air, or serves as a channel through which the air current passes to the lower part of the burner. In one lamp which has been described (see p. 366) the annular space between the two glasses is filled with compressed air, and is thus used in connection with an automatic safety appliance. The obvious object of the double glass is to minimise the risk which may attend the fracture of the single glass. The air between the two glasses materially reduces the amount of heat which would otherwise be conveyed from the flame to the outer glass, and the liability to fracture of this glass is diminished; but, on the other hand, the inner glass is necessarily brought into close proximity to the flame, and is very liable to break through local overheating, especially when the lamp is used in an inflammable atmosphere, which may ignite and burn round the bottom of the inner glass. Moreover, when the inner glass breaks, the character of the lamp becomes altered, its internal capacity, for instance, being largely increased; the lamp may therefore by such fracture be rendered unsafe, even though the outer glass remains intact. Double glasses have also been objected to on the score that it is troublesome to get them to fit well.

Flat glasses have been employed in a few instances, in tin-can Davy lamps, and in some of the early forms of safety lanterns to which attention has been drawn.

The glasses are, as a rule, supported between the lower and middle rings of the frame, and are secured in position by the auxiliary ring screwing into the lower frame-ring. As it is important that the junction between the metal and the glass should be gas-tight and remain so, it is customary to place washers between the surfaces, so as to allow of the unequal expansion and contraction of the two materials. For this purpose, rings of leather, india-rubber, and various compositions, have been used, but none of these has been found capable of resisting the alternate heating and cooling to which it is subjected. Asbestos rings have, however, been found to answer admirably, and were accordingly recommended by the Royal Commissioners.

Mica has been used in the place of glass by Parish, Fyfe and Hewetson, as well as in the Pendleton lamp, Biram's lamp, and other lamps. It no doubt possesses the great advantage over glass that it will not crack as glass does when flame directly impinges upon it, but under the influence of strong heat it soon becomes brittle, and is then liable to be broken by a blow or by pressure. Moreover, a mica cylinder must necessarily be weak, and must be made with at least one joint, which is liable to be unsound. Mica therefore cannot be regarded as a desirable substitute for glass.

A protecting shield of mica has occasionally been fitted round the glass, but even this is not a satisfactory addition. The only manner in which

mica appears to have been usefully employed in the construction of safety-lamps is in the forming of what may be termed windows in the bonnet, through which the miner is enabled to inspect the gauzes and thus to ascertain whether they are becoming dangerously hot. For this purpose, strips of mica mounted in metal frames are set in slots in the bonnet.

The Gauze.—There remains but little to be added to the description already given of gauzes for safety-lamps. A safe gauze should bear a definite relationship to the volume confined in the lamp and the surface open for the escape of burnt gases; the conical form has been found to give the best results. The mesh, at any rate in the case of the safety or protective gauze, must be such that there are not less than twenty-eight meshes to the linear inch. In a series of gauzes, a larger mesh may perhaps be permissible for the inner ones. Gauzes of smaller mesh than this have at various times been employed. It is important that all junctions in the gauze should be well made, so that no openings may be left; accordingly, the ends and edges are generally made to overlap and are fastened together by folding and pressing or by wiring. Sometimes unmounted gauzes are employed, but the neatest and most effective method of applying gauzes to safety-lamps is to mount them in sheet-metal collars. The gauze is well supported when held between two properly fitting bands, and these bands may be flanged and shaped so as to fit over the top of the glass, or under the rim of the bonnet. In this way, a far better junction can be made than is possible with the unmounted gauze.

Copper, brass, iron, and even silver have been used for the manufacture of the gauze; it is generally of the ordinary type, but woven gauzes of special description have occasionally been adopted. In the Schöne lamp, for instance, the gauze resembled basketwork, and in its behaviour towards heated gases was similar to ordinary gauze doubled.

The Shield or Bonnet—These are invariably of sheet metal; either copper, brass, iron, zinc, or tinned iron. In some cases they take the form of plain cylinders; in others they are perforated for the admission of air and escape of products of combustion; and occasionally they are mounted in a ring of metal, generally brass, perforated to allow of the entrance of air. Special additions are sometimes made to the bonnet, such as the upper batten or flange in the Evan Thomas lamp, Fig. 327, and the batten in the Thorneburry. The bonnet is also frequently provided with a cover. In some cases, the bonnet performs a particular function in addition to affording protection; thus in one form of the Howat deflector lamp, the bonnet forms part of the deflector system, Figs. 329 and 330; and, as has already been explained, the bonnet has been used by Thomas as an automatic extinguisher. In the sight light lamps, a glass shield is used, and is protected by a sheet-metal continuation of the frame which has four long openings in it so that the gauzes can always be seen.

Oils used as Illuminants.—It is obviously in the highest degree important that the safety-lamp shall be capable of furnishing a sufficient and uniform light during the whole period that it is in use. Safety is, however, the first consideration, and the principles of construction which experience has shown to be essential in minimising the risk of communication of flame to an explosive atmosphere, are incompatible with the attainment of high illuminating power. The Marsaut lamp with a wick 0.5 inch in breadth, held by a burner 0.4 inch in breadth, furnishes with a good oil a flame which in the lamp with two gauzes has an average illuminating power of about 0.4 of a

candle. Nevertheless, the efficiency of the safety-lamp as a source of light largely depends on the selection of a suitable illuminant. The Royal Commissioners, who carefully investigated this matter, came to the conclusion that seal oil was better than rape oil (colza oil), and that a mixture of seal oil or rape oil (preferably the former) with half its volume of petroleum having a flashing point not lower than 80° F., was far superior as an illuminant.

Vegetable and animal oils are more viscous than mineral oils, and ascend the wick by capillary attraction less readily; moreover, when subjected to the heat of the lamp they gradually undergo a chemical change with the result that the defects referred to become aggravated. The addition of petroleum to the fixed oil largely decreases the viscosity of the latter, causes it to pass up the wick far more freely, and very considerably diminishes the liability to oxidation.

In the Protector lamps, the illuminant employed is petroleum spirit (benzoline), and the oil vessel is packed with an absorbent material on the principle of the "sponge lamp" in which this spirit is burned for domestic purposes. The lamp is charged by saturating the sponge with the illuminant and draining out any excess of the latter by inverting the oil vessel; in this way the danger which would otherwise attend the outflow of so volatile and inflammable a liquid, in the event of the lamp being overturned, is removed. It is, however, essential to safety that the charging of these lamps should be effected where the combustible vapour which escapes cannot be a source of danger by forming an explosive mixture with air or otherwise, and, having regard to the character of the liquid, the Royal Commissioners commented strongly on its introduction for use in mines under the "dangerously misleading name" of colzalene. The Commissioners found that benzoline in the Protector lamp yields a bright flame, very easily extinguished by a current of air. The flame remains of nearly constant intensity during the whole time of a shift, the wick does not become charred, indeed the upper part is of asbestos-wool, as already mentioned, and there is no need for the employment of a pricker.

In the Thorneburry lamp a description of petroleum intermediate between the ordinary burning oil and lubricating oil, having a specific gravity of about .830, and a flashing point (Abel test) not below 250° F., is successfully employed, the illuminating power of the lamp being very decidedly superior to that of any of the safety-lamps which were made the subject of experiment by the Commissioners. Solid paraffin of low melting point has also been used in miners' lamps.

In the preceding account, an attempt has been made to trace the evolution of the safety-lamps employed by miners, to classify as far as possible the very numerous designs which the fertile brains of many inventors have produced, and to indicate some of the merits and defects of the principal forms. Within the scope of such an article, it has not, of course, been possible to treat the matter exhaustively, and it has been the aim of the Authors to furnish a general descriptive account embodying only such mechanical details as are necessary for a comprehension of the principles of construction and the characteristic features of the lamps. References have been made to certain lamps which have not come into practical use, but this has only been done in cases where some new arrangement worthy of consideration has been adopted.

In some instances, remarks in reference to the utility of the various devices described have been made, but instead of attempting any systematic criticism it has been thought desirable to append the following particulars

obtained largely through the courtesy of H.M. Inspectors of Mines, which indicate the character of the safety-lamps now in use.

In North and East Lancashire, in 1889, there were, according to Mr. J. Dickinson, 26,327 safety-lamps in use, of the following types.

Davy	1,449	
„ Improved	1,287	
„ „ Jack	311	
„ „ Donald	56	
		3,103
Marsaut		18,800
Mueseler		5,555
Park Lane		704
Bonneted Clanny		677
McKinless		137
Mercier		128
Hepplewhite-Gray		61
Evan Thomas		50
Wall's Deputy		8
Bainbridge		2
Hall's Deputy		2

In Yorkshire, all the best-known types are in use in different parts of the county.

In Derbyshire, Leicestershire, Nottinghamshire, and Warwickshire, Mr. A. H. Stokes reported that there were in use in 1890.

Marsaut	17,521
Bonneted Clanny	8,050
Mueseler	3,393
Clanny	2,336
Various	1,590
Davy	395

Making a total of 33,285.

In Staffordshire, the types most commonly employed are the Marsaut and the Mueseler, with some Bonneted Clannys and Deflectors.

In South Wales, in 1890, Mr. J. T. Robson found in use about 49,000 safety-lamps of the following types.

	Bonneted Clanny and Cambrian.	Mueseler.	Marsaut.	Davy (shielded).	Clanny (shielded).	Cambrian (Fireman's).	Hepple-white-Gray.	Davy.	Clanny.	Total.
The Property of the Colliery Owners	10,575	306	3,301	140	122	134	11	271	2	14,862
The Property of the Workmen	25,756	—	—	—	5475	20	—	3	—	31,254
Estimated number at eight collieries from which no returns were obtained										2,884
Total number of safety-lamps in use										49,000

Note.—From the foregoing tabular statement, it will be seen that the miner not unfrequently provides himself with a lamp.

In Scotland, safety-lamps are less generally used than in England. The

following figures furnished by Mr. Joseph T. Martin indicate the relation which the number of safety-lamps in use bears to the number of persons employed and the quantity of coal won in the South-Western district.

	Safety-Lamps in Use.	Persons Employed.	Output.
1875 ...	1,755 ...	34,136 ...	6,437,322
1880 ...	2,949 ...	29,811 ...	7,997,879
1885 ...	5,047 ...	35,659 ...	9,478,018
1890 ...	9,400 ...	40,938 ...	10,223,922
1892 ...	12,262 ...	42,612 ...	10,200,044

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